PHILIPS electronic engineer

Instructionbook | EE 1003

CIRCUITS FOR EE 1003

A1 TWO-STAGE AUDIO AMPLIFIER
A2 PUSH-PULL AUDIO AMPLIFIER
A3 THREE STAGE AMPLIFIER WITH FEED-BACK

B1 MORSE CODE TRAINING SET
B2 TELEPHONE AMPLIFIER
B3 GENERATOR FOR TELEPHONE SIGNALS

C1 THREE TRANSISTOR REFLEX RECEIVER
C2 SUPER REGENERATIVE RECEIVER

D1 TELL-TALE LIGHT
D2 TRAFFIC BEACON WITH ADJUSTABLE FREQUENCY
D3 FLASHING LIGHT WITH ADJUSTABLE FREQUENCY
D4 ACOUSTIC RELAY
D5 PILFERING ALARM
D6 BURGLAR ALARM
D7 TWO TRANSISTOR DIRECTION INDICATOR
D8 THREE TRANSISTOR DIRECTION INDICATOR
D9 GENERATOR FOR TWO-TONE SIGNAL

E1 AUTOMATIC NIGHT LIGHT
E2 WETNESS INDICATOR WITH INDICATION LIGHT
E3 WETNESS INDICATOR WITH SOUND SIGNAL
E4 TIME SWITCH WITH INDICATION LIGHT
E5 TIME SWITCH WITH SOUND SIGNAL
E6 LIGHTMETER WITH INDICATION LAMP
E7 MEASURING BRIDGE FOR RESISTORS, COILS AND CAPACITORS

CIRCUITS IN COMBINATION WITH ME 1201

EM1 MOTORCAR
EM2 CAR WITH TWO-TONE KLAXON
EM3 CAR WITH ELECTRONIC DIRECTION INDICATORS
EM4 CAR THAT STOPS WHEN MOVING ON TO A DARK FLOOR AREA
EM5 CAR WITH AUTOMATICALLY LIGHTING HEAD LAMPS
EM6 LIGHT-ACTIVATED SIREN
EM7 CAR WITH STOP LIGHT
EM8 CAR THAT REDUCES SPEED IN THE DARK AND LIGHTS HEAD-LAM AUTOMATICALLY
EM9 CAR THAT STOPS ON DARK FLOOR AREA AND STARTS AGAIN AUTOMATICALLY
EM10 LEVEL CONTROL
EM11 ADJUSTABLE MAXIMUM-SETTING SWITCH
EM12 OBSTACLE LIGHT

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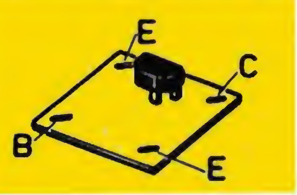
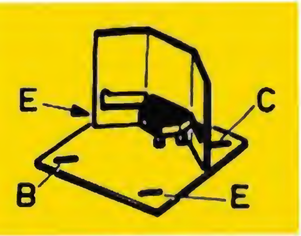
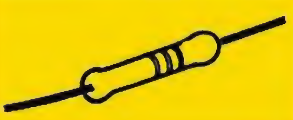
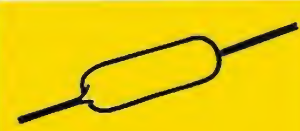
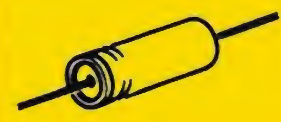
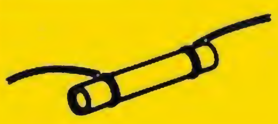
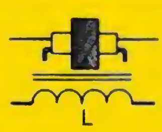
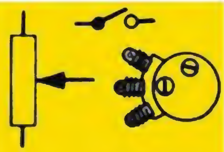
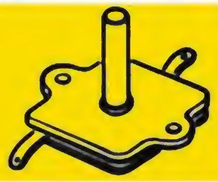
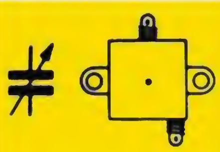
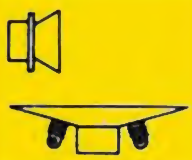
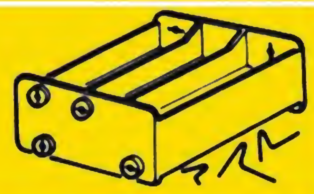
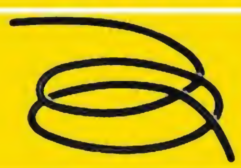
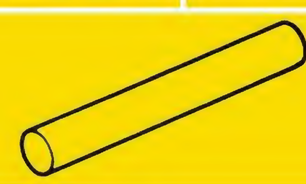
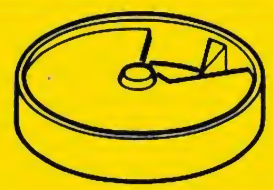
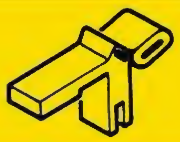
Instructionbook

CONTENTS

COMPONENT AND SYMBOL		No.	DESCRIPTION	Quan-tity
		1	Transistor (T) BF 194	1
		2	Transistor (T) BC 148	2
		3	Diode (D) OA 85	1
		4	**Resistor (R)** 1x 10 ohm 1x 1.500 ohm 2x 22.000 ohm 1x 47 ohm 1x 2.200 ohm 2x 47.000 ohm 1x 100 ohm 1x 3.300 ohm 1x100.000 ohm 1x 220 ohm 2x 4.700 ohm 1x220.000 ohm 1x 470 ohm 2x10.000 ohm 1x470.000 ohm 1x1000 ohm 1x15.000 ohm	21
		5	**Polyester Capacitor (C)** 1 x 0.22 μF 1 x 47.000 pF (= 47 nF) 2 x 0.1 μF 1 x 22.000 pF (= 22 nF)	5
		6	**Electrolytic Capacitor (C)** 2 x 125 μF 1 x 10 μF 1 x 4 μF	4
		7	**Ceramic capacitor (C)** 1 x 10.000 pF 1 x 47 pF 2 x 10 pF 1 x 1000 pF 2 x 22 pF	7
		8	Choke coil (L)	1
		9	**Aerial coil (L)** 1 = red 3 = green 2 = yellow 4 = grey	1

		10	Light dependent resistor (LDR)	1
		11	Potentiometer (R) with switch 10.000 ohm	1
		12	Variable capacitor (C) 5 - 180 pF	1
		13	Loudspeaker 150 ohm	1
		14	Lamp 6V, 0.05 A	1
		15	Batteryholder with springs for 6 penlite cells	1
		16	Bare wire	10 m
		17	Insulated wire	10 m
		18	Ferroxcube rod	1
		19	Rubber grommet	2

	20	Hairpin spring	50
	21	Large coil spring	50
	22	Small coil spring	20
	23	Dial knob	1
	24	Plate for mounting variable capacitor	1
	25	Knob	1
	26	Lampholder	1
	27	Window for lamp	1
	28	Rubber band	5
	29	Lever	1

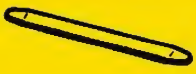
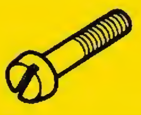
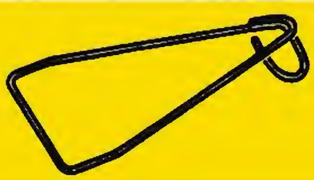
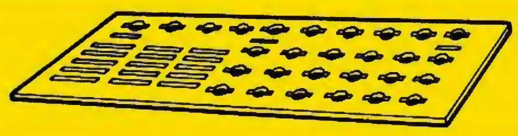
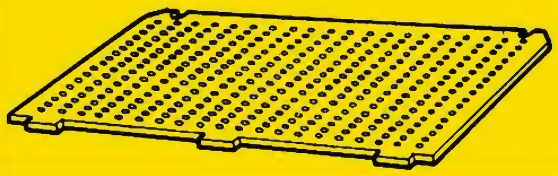
	30	Contact spring for lever	1
	31	Bracket for lever	2
	32	Grub screw (3 mm)	2
	33	Square nut (3 mm)	4
	34	Washer for potentiometer	1
	35	Washer for bracket 37	4
	36	Screw (3 mm)	2
	37	Bracket for mounting panel	2
	38	Frontpanel	1
	39	Mounting plate	1

Table 1

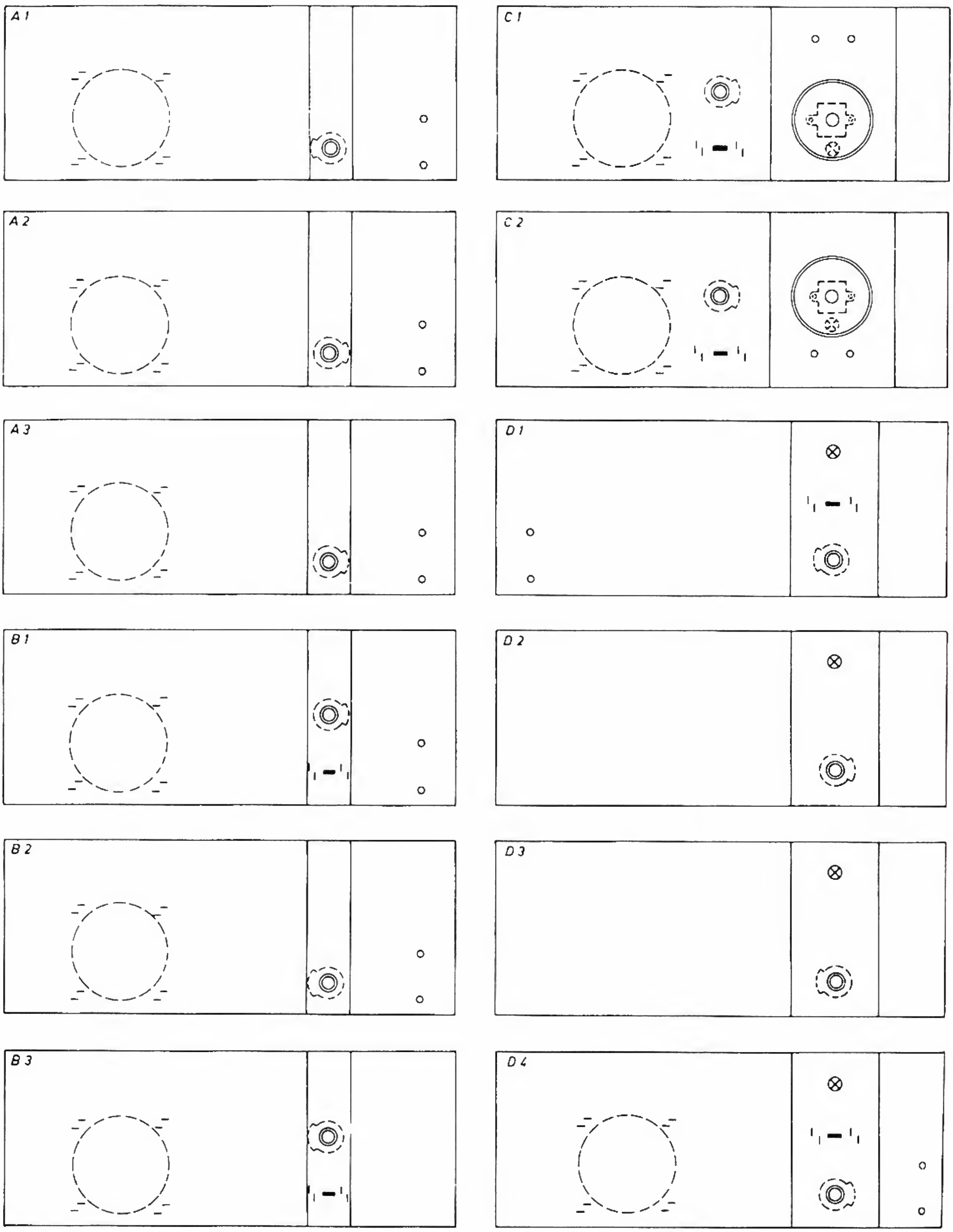
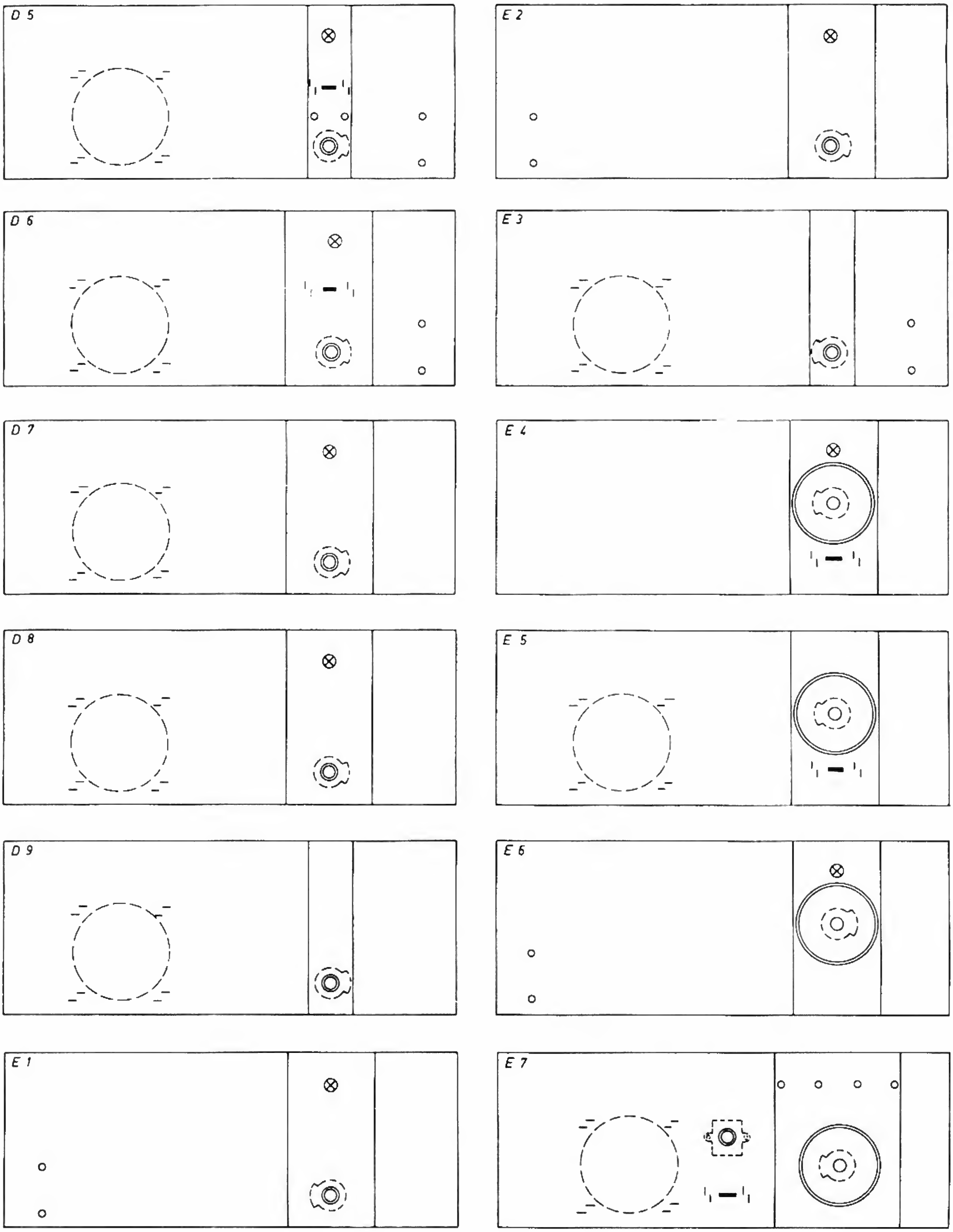


Table 1 (Continue)



SEQUENCE OF CONSTRUCTION

In this experimental-box you'll find, besides diagram-cards marked A1, A2, A3 etc., some large and small printed cards. These are intended to screen the unused holes in the front-panel. When you're starting to experiment, first look up in table 2 which frontcard and which overlay-strip you will need for that experiment. Then put together the assembly-panel; and after that, the large parts, such as loudspeaker, variable capacitor, potentiometer, push-button, lamp etc., as far as required. The place for fixing these parts is given in table 1.
You must finish this part first before you start with the assembly of the resistors (see page 37), capacitors, transistors, etc. and the wiring.
On the assembly-card you can see exactly where each part must be placed. In the package of frontcards you will find some punched out cardboard pieces, which can be glued onto the inside of the pointer-knob (23). The thin strips are meant to cover the conical part and the half-moon shapes are put onto the flat part.
In those cases where dial-lighting is applied, as in circuits C1 and C2 the bulb is mounted below the big knob. The white cardboard reflects the light which gives a better view of the dial.

Warning

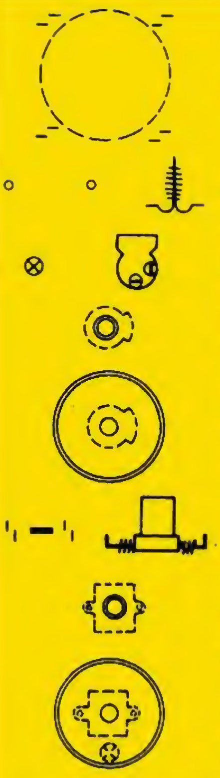
Before you connect the batteries, or switch on the set, first check for mistakes (see page 36).

THE MOUNTING-PANEL

Take the mounting plate (39) in front of you, with the tabs away from you. Take the circuit-card of the set you want to build and put it on the mounting plate as indicated, so that to the left one row of holes and below three rows of holes remain uncovered and the card number is legible from your side. Now the hairpin springs (20) are pushed through the holes at the connecting points in an upward direction (fig. 1). No spring must be placed in the circled, feed-through holes. Next put the mounting plate flat on the table and push the large coil springs (21) over the hairpin springs.
Now take the two brackets (37) and put two washers (35) on each of them and push the washer 'until it reaches the enlarged part of the bracket. (fig. 2). Lay the correct front card against the front panel and put the overlay strip over this, so that the holes match those in the front card. Fold the overlay strip against the back of the front panel (fig. 3). Now place the brackets with washers in the four

Table 2

Circuit	Frontcard	Overlay	Circuit	Frontcard	Overlay
A1	A	4	D5	A	–
A2	A	4	D6	A	8
A3	A	4	D7	A	5
B1	A	3	D8	A	5
B2	A	4	D9	A	4
B3	A	3	E1	C	5
C1	B	1	E2	C	5
C2	B	2	E3	A	4
D1	C	8	E4	C	–
D2	C	5	E5	A	7
D3	C	5	E6	C	6
D4	A	8	E7	B	–



	Loudspeaker
	Outside connections on the front-panel
	Indicator lamp
	Potentiometer with knob
	Potentiometer with dial knob
	Lever
	Variable capacitor with knob
	Variable capacitor with dial knob and lighting

Table 1 (continue)

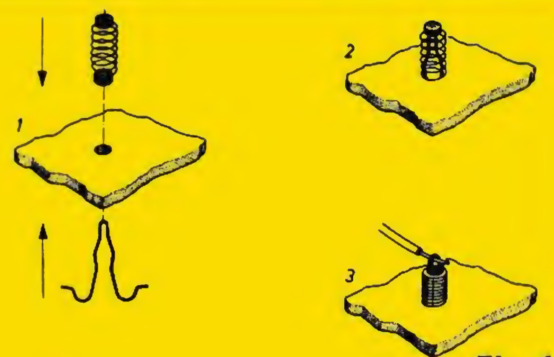


Fig. 1

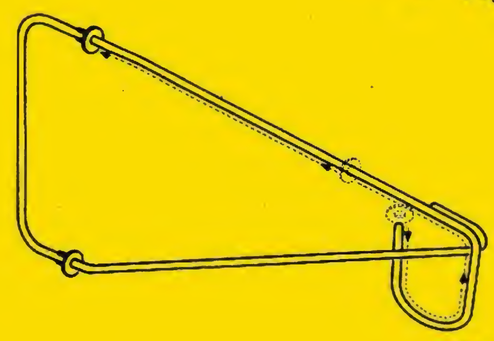


Fig. 2

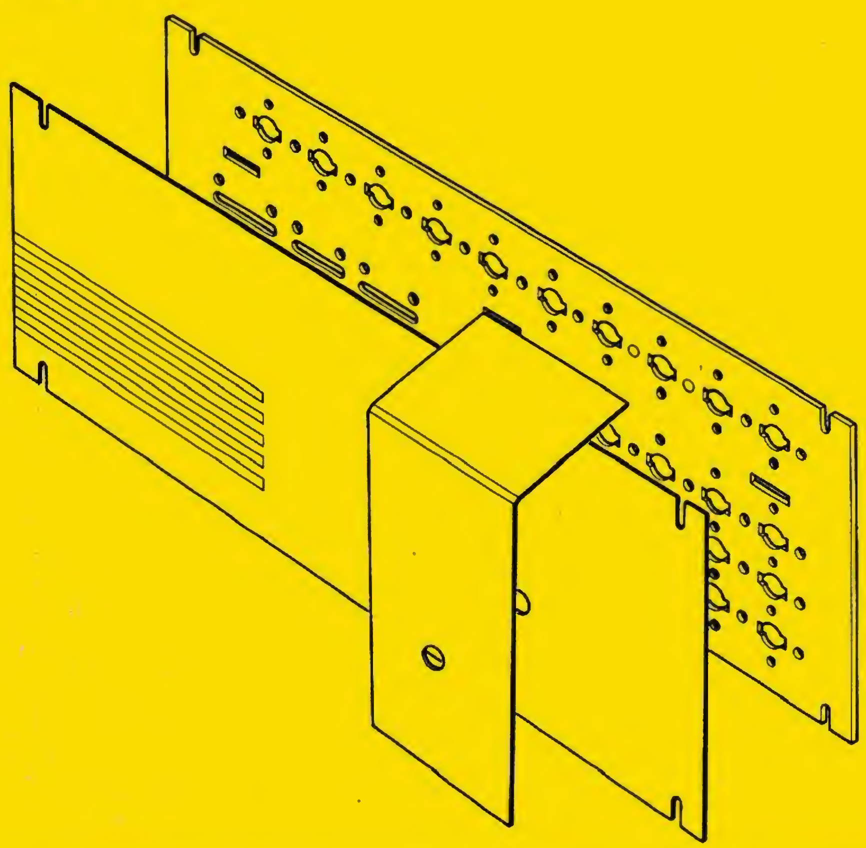


Fig. 3

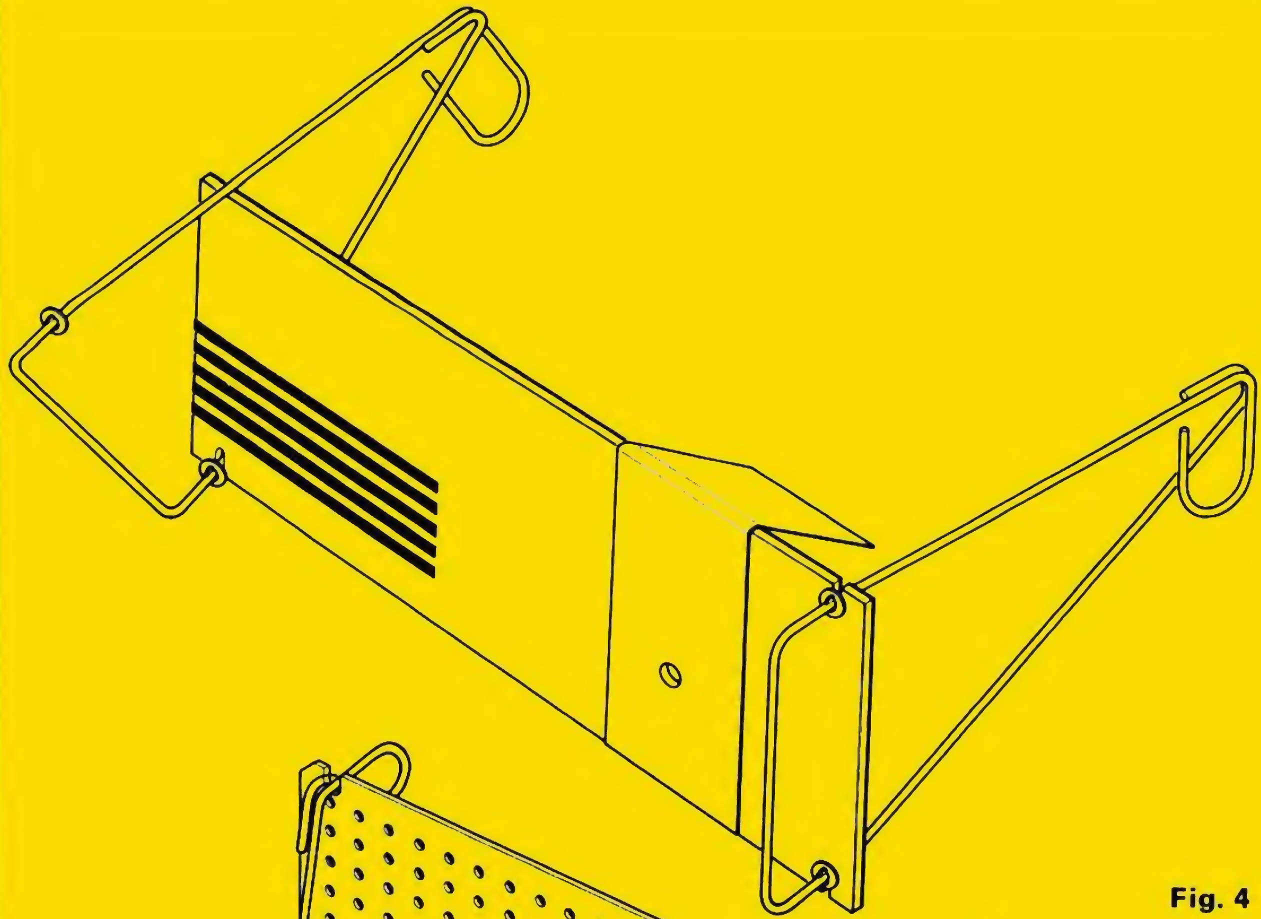


Fig. 4

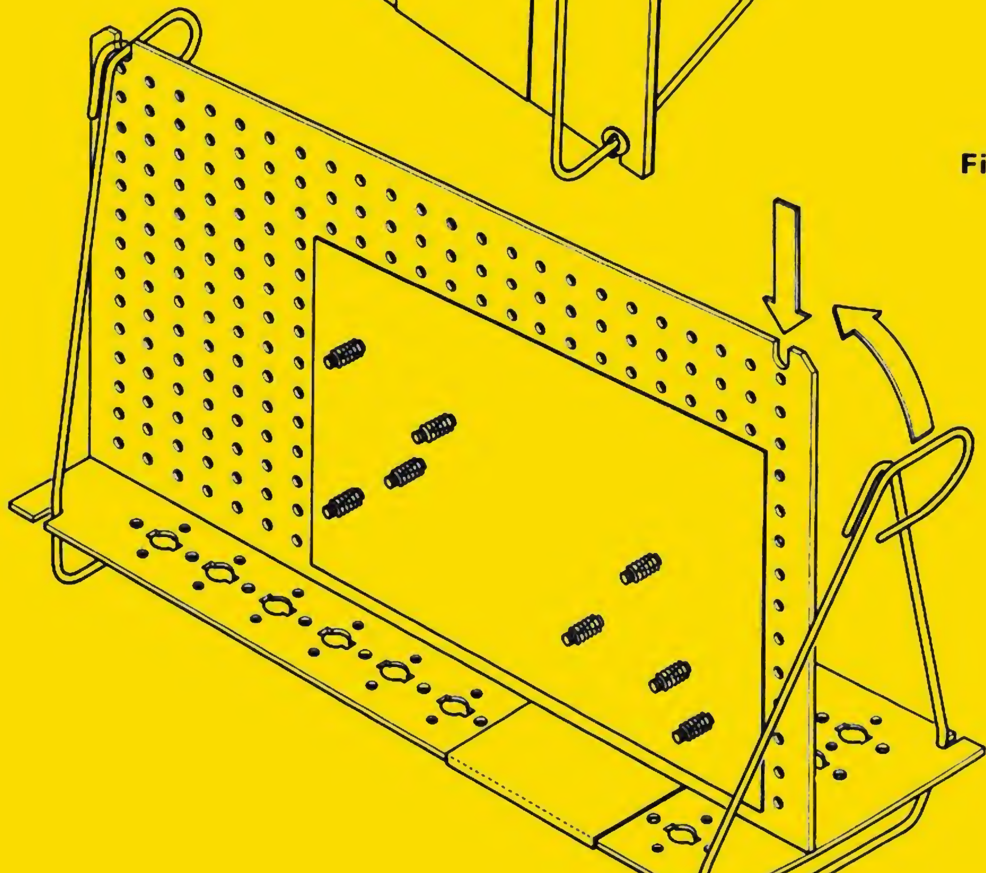


Fig. 5

slits near the corners of the front panel (fig. 4).
Put the mounting plate and frontplate together with the tabs of the first in the slits of the latter.
The folded part of the overlay strip is now held between the two plates. Pull the brackets one after another over the back of the mounting plate until they fall into the slits (fig. 5). By doing this the front panel may bend slightly.
Onto the uncovered holes of the front we now fix the controlling devices, loudspeaker, indication lamp, etc. Table 1 (page 6 and 7) indicates what is needed for each circuit. In a few cases a hole is left open.

FIXTURES

Loudspeaker (fig. 6)

Put four hairpin springs into the front panel from the outside. Put the mounting holes of the speaker over the springs. Push four large coil springs (21) over the hairpin springs.

Potentiometer (fig. 7)

Push the shaft of the potentiometer through the hole (table 1). Attach the potentiometer with a washer (34) and a nut.

The variable capacitor (fig. 8)

Attach the capacitor to the front panel with two screws and two nuts. Do not forget to put the plate (24) in between them or the shaft will protrude too far.

Pushbutton (fig. 9)

Push two hairpin-springs through the front-panel from the outside and push large coil springs over them. Put the small brackets (31) from both sides into the

Fig. 6

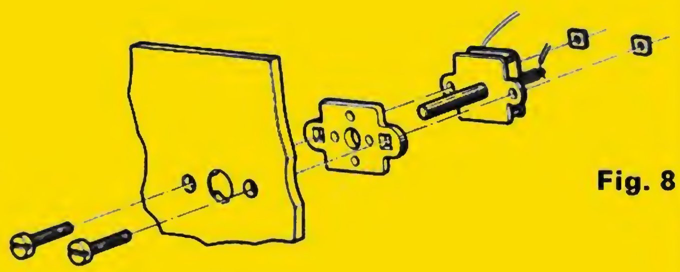


Fig. 8

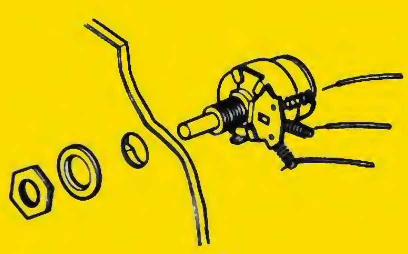


Fig. 7

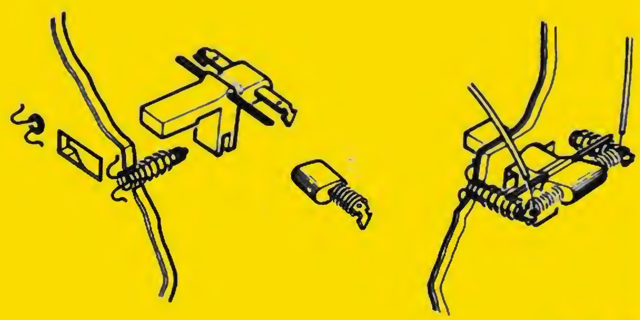


Fig. 9

lever. Push the small coil springs (22) over these brackets.
Slide the contact spring (30) into the groove of the lever. Put the assembly with the points of the brackets into the hairpin-springs. The wires are connected by pushing the springs (22) against the lever and sticking the bared ends into the holes of the brackets.

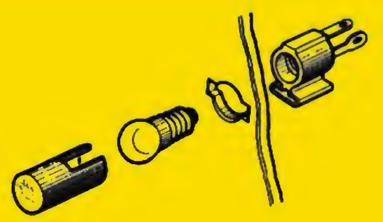


Fig. 10

Indicator Lamp (fig. 10)

Hold the lampholder (26) behind the hole and screw the lamp (14) into it through the hole. Slide the red lamp cover (27) over the lamp with the tabs over the lampholder.

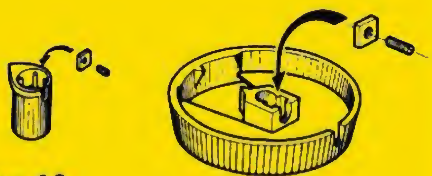


Fig. 11 en 12

Knobs (fig. 11 and 12)

Put a grubscrew (32) into a square nut (33) for only a few turns. Put this assembly into the rectangular hole of the knob. Slide the knob onto the shaft and secure it by tightening the grubscrew. Tighten the dial knob in such a way that the pointer indicates the letter P when turned to the right.

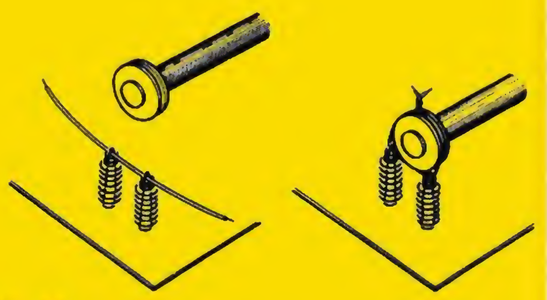


Fig. 13

Aerial rod (fig. 13)

Slide the aerial coil (9) over the ferrox-cube rod (18). Put a rubber grommet on both sides (19). Take two pieces of wire (about 8 cm) and stick them through the hairpinsprings on which the rod must be mounted. Pull the wire through the slots of the grommets and twist the ends. The copper core of the ends must not make contact.

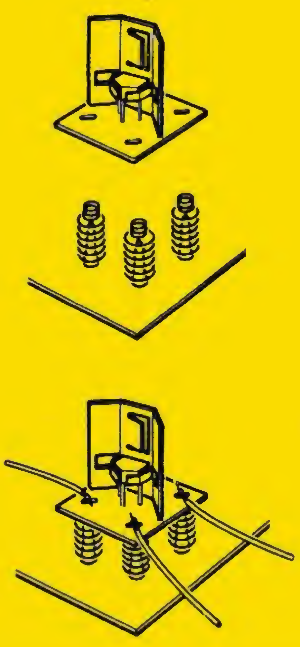


Fig. 14

Transistors (fig. 14)

Slide the slotted base plate over the three hairpin-springs. See that these springs are put in the right position. Push the plate down and push connecting wires through the springs.

Battery holder (fig. 15 and 16)

Put the springs into the battery-holder in

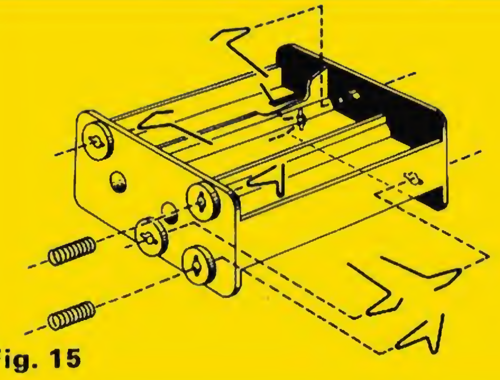


Fig. 15

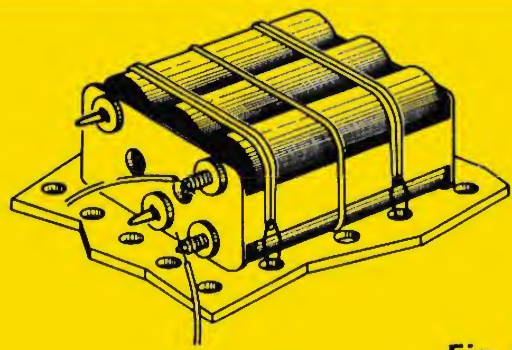


Fig. 16

accordance with fig. 15, and put in the cells at the same time.
Put a rubber band around the battery-holder, so that the cells cannot fall out. The correct position of the cells is indicated on the battery-holder. Attach the assembly onto the mounting plate with the aid of two rubber bands and four hairpin-springs.

Attachment of wires to loudspeaker, potentiometer, lamp etc.

A small coil spring (22) is slid over the contact lugs of the part in question. Push back the spring, stick the bared end of the wire (about 7 mm) into the hole of the lug and release the spring.

Outside connections on the front-panel

A hairpin-spring is put into the hole from behind.
The bared end of a piece of wire is also put through the hole and then a large coil spring is pushed over on the front side. Push the large coil spring firmly so that the wire is squeezed tightly between the spring and the panel and cannot be pulled out.

Circuit descriptions and data

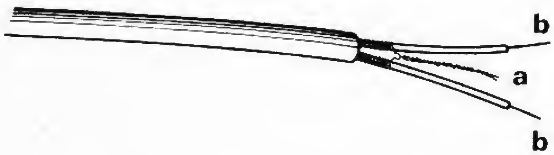
More explanation and data about the working of the various circuits is given from page 14 to 18 and 19 to 33.
In the chapter "How do electronics work" more is said about the technical details and the working of the various components.

WARNING
Do not tamper with the mains as these voltages are more than enough to cause a fatal accident.

CIRCUIT DESCRIPTIONS AND DATA

A. ELECTRO ACOUSTICS

In this chapter amplifiers will be described. They all serve to amplify the strength of weak sound signals in such a way that they can be reproduced by a loudspeaker. The weak AC voltages passed through the input of such an amplifier may originate in, for example, a microphone, record-playing equipment, or a tape-recorder. A record player has a screened cable to connect it to an amplifier. Attach the screen (a) to the minus and the one or two cores (b) to other connection springs (fig. 17).



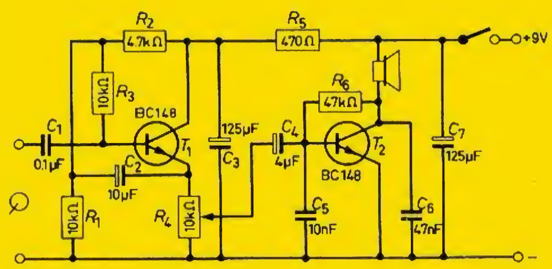
The amplifier is required not only to amplify these AC voltages sufficiently for reproduction via a loudspeaker, but also to allow only a minimum of distortion, (the electrical vibrations must retain their original shape), and to cause no great changes in the ratio of the sound volume of high and low tones, and to make sound volume control easy.

A1 Two-stage gramophone amplifier

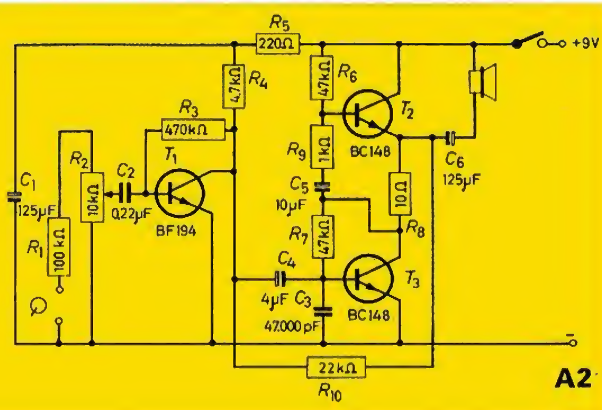
Two normal amplifier stages are arranged in cascade.
The first stage is designed as an emitter follower.
The input resistance of this circuit is so high that a crystal pick-up can be connected directly to the input without the risk of attenuation of low notes.
The emitter follower can deal with such strong signals that we can leave out a volume control between the input and the first transistor. This is now placed between the emitter follower and the final amplifier. The resistor R5, with the electrolytic capacitor C3, forms a filter which keeps fluctuations in the battery voltage away from the preamplifier.

A2 Push-pull audio amplifier

The output stage of this amplifier differs from what we have seen up to now. It is a push-pull stage, which means to say that the changes of current in the two transistors are opposed to each other. While the current through transistor T2 increases, the current through transistor T3 decreases, and vice versa.
As we can see, the two transistors are connected in series across the battery voltage, so that it is a little difficult to imagine that the currents through them can differ from each other. The reason why this is possible is that the fluctuations in the current are very rapid, as



A1



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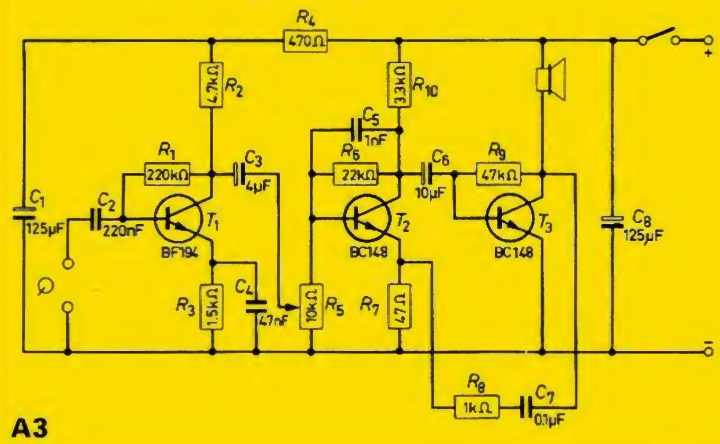


A3

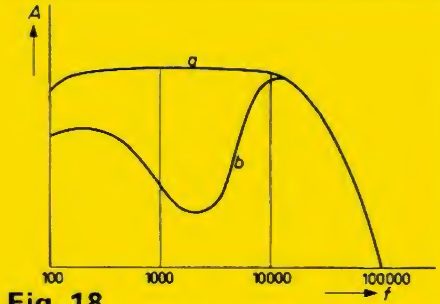


Fig. 18
a - Frequency characteristic without feedback.
b - Frequency characteristic with feedback.

mentioned on page A16, so that we can consider these fluctuations as those of an alternating current. This alternating current, which is the difference between the currents of the two transistors, can pass through the electrolytic capacitor to the loudspeaker. The average current (direct current) through the two transistors is then the same.
Here then, we have the advantage that the loudspeaker passes alternating current but no direct current. A further advantage of this push-pull circuit is that it gives rise to less distortion, since small differences in the transistor characteristics are balanced out. In most push-pull circuits both output transistors are controlled directly by the preamplifier, but in this circuit it is different. The transistor T1 controls the transistor T3, and the collector (alternating) current of this transistor passes not only through the loudspeaker but also through a resistor R8. The AC voltage appearing across this resistor controls the transistor T2 via R9 and C5.

A3 Three-stage amplifier with feedback

With three amplifier stages in cascade this circuit produces much more amplification than required. We make use of this by the addition of feedback. By this we mean the feeding back of part of the output voltage of the amplifier to the input. This is done in such a way that the input voltage is opposed. Such feedback can be added to one or more amplifier stages. In the circuit diagram we see that the voltage is fed back from the loudspeaker via the capacitor C7 and the resistor R8 to the emitter of transistor T2. This represents feedback over two stages. But the capacitor C5 between the collector and the base of the second transistor gives rise to feedback over one stage.
Let us imagine that we have an amplifier which requires an input voltage of 0.1 V to supply an output voltage of 10 V (amplification 100 x). If now we take 0.9 V from the output voltage and feed it back to the input in such a way that the input voltage is opposed, we must now supply 1 V to the input (the difference is 0.1 V) to obtain an output voltage of 10 V again.
With feedback the amplification is now really only 10 x, whereas originally it was 100 x. Then we say that the amplification has a tenfold feedback. Feedback improves many properties of an amplifier, but diminishes the amplification of them. The principal improvement lies in the reduction of distortion. If we make sure that the output voltages of different frequencies are fed back with different strengths, then the amplification does not become reduced equally for all tones. In this way we can introduce changes into the frequency characteristic of the amplifier (fig. 18).

B COMMUNICATION

In various circuits of this kit we find oscillators, e.g. in circuits B1 and B3. Oscillators generate an A.C. voltage of a certain frequency and this frequency depends on the value of the components that have been used. It will mostly be between 10 Hz and 100 kHz.

We can see two main groups:

a - LC-oscillators, the frequency of which is determined by one or more coils and capacitors of the circuit.

b - RC-oscillators, the frequency of which is determined by one or more resistors and capacitors of the circuit.

The LC-oscillators filter a certain frequency out of a signal that is a composition of a large number of frequencies. For that reason the quality of the generated signal does not need to be very good and the tolerances of the various components can be somewhat larger. The disadvantage however, is that for low frequencies they are very expensive, very bulky and very difficult to vary in frequency. But for high frequencies, they are often used because these disadvantages are not encountered and because they give the advantages mentioned above. The RC-oscillators have to be adjusted very carefully with feed-back. Therefore they are dependent on the tolerance value of the various components. Also a constant battery voltage is very important.

B1 Morse-code training set

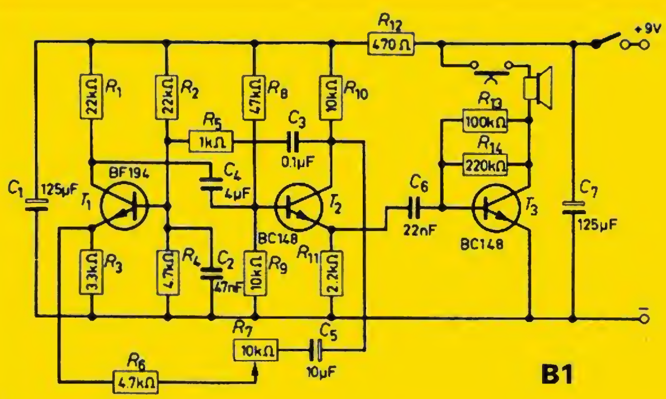
A real morse key can be connected to the two connection springs on the front. This circuit has two parts, the oscillator, transistors T1 and T2 and an amplifier stage, transistor T3. The amplifier stage amplifies the signal so that it can be reproduced by a loudspeaker.

The RC-oscillator feeds back over a so called "Wienbridge" (fig. 19). This is a special type of oscillator which gives an A.C. voltage of a very constant frequency. In this circuit the amplification needs to be only three times. In fact it is far greater which causes the signal to be distorted. Therefore we have variable feed-back via C5, R7 and R6 which decreases distortion. When the feed-back is adjusted very accurately with R7 the circuit gives a very good sinusoidal signal.

When the feed-back is decreased, the increasing distortion can be heard very clearly. When the battery voltage decreases the feed back has to be decreased too.

B2 Telephone amplifier

This is a 3-stage amplifier with all transistors in common-emitter circuitry, giving a large amplification. The choke-coil is switched to the input of the amplifier (via a long twinlead). Fig. 20 shows how it is possible to connect the pick-up coil to a cable of a certain length. This coil gives a signal when it is situated in a



B1

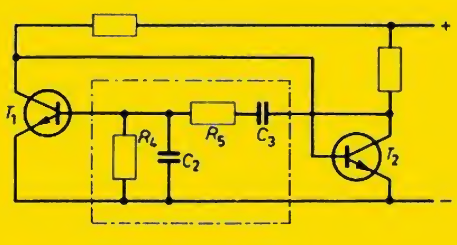
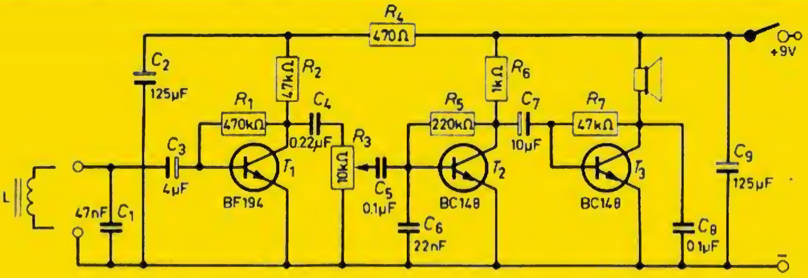
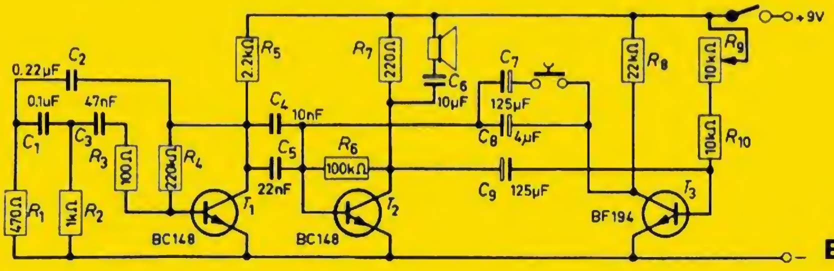


Fig. 19. Wienbridge



B2



B3

low frequency magnetic field. Such a field we find near a telephone because of the presence of an iron core choke coil or a transformer. The best place to pick up a signal has to be determined by

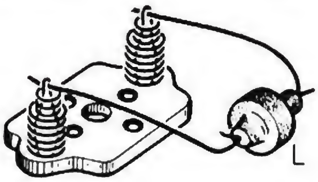


Fig. 20

experience.
The signal that comes from the coil is so small that it can be fed directly to the first stage without running the risk of overload.
The volume control is placed between the first and the second stage. The signal at the input is limited by the capacitors C1, C4, C5 and C6, allowing only the speech frequencies to pass.
The large amplification makes this necessary, otherwise the apparatus would pick up hum or would become unstable.
Another form of instability can occur when the coil is held near the loudspeaker of the circuit.

B3 Generator for telephone signals

This circuit generates the signals that are used by the Post Office for the telephone. This circuit has two parts. First, the RC-oscillator with transistor T1 that gives a tone of a certain frequency. This tone is fed to the second part, a multivibrator with transistors T2 and T3.
A multivibrator is an electronic switch which opens and closes at a certain frequency. In this case the transistor T2 is opened and closed periodically. The tempo can be lowered by closing the switch near C7.
The transistor T2, when conducting, amplifies the signal from the oscillator and passes it to the loudspeaker.
The loudspeaker cannot be switched directly to the collector of T2, because the inductance and the resonance of the loudspeaker influence the proper working of the multivibrator.

C RADIO.

The detection system described on page A29 is the one used in practically all broadcast receivers. The reason is that it is simple and reliable, offers a good performance, and the AF-signal after development has the same shape as the modulation of the carrier. However, there are also disadvantages, the most important of which is, that a diode detector can only work in a certain voltage range e.g. 0.1 - 10 volts.
When the carrier voltage is too low the efficiency of the detector drops which causes lower sensitivity and increased distortion. In principle, it is no problem to make a detector work at voltages of over 10v, but feeding a loudspeaker with a detector leads to quite impractical and uneconomic circuitry.
For this reason, we find that in any normal receiver one or more high frequency (also called radio frequency RF) amplifier stages precede the detector and one or more AF-amplifier stages follow. We also find this in the receiver C1 with the unusual deviation, that the first transistor functions both as RF- and AF-amplifier. In more elaborate receivers that must be very sensitive, it may be necessary to put as many as three amplifier stages between aerial and detector. However, this leads to constructional difficulties, which we will not discuss in detail here. We can overcome these difficulties by adopting the "superheterodyne" principle.
The diode detector about which we spoke above is not the only one we use in this kit. In the receiver circuit C2 that is intended to receive VHF (very high frequencies) we make use of a "super regenerative detector".
This detector has a number of disadvantages, but one excellent property kept it in use; great sensitivity obtained by relatively simple means.

Outside aerial and earth

In the transmitter the aerial serves to emit the radio waves; in our receiver, the aerial picks up the radio waves again. An outside aerial consists of a wire suspended between two high points, e.g. chimneys, and connected to the receiver. Such a big outside aerial naturally picks up more than a ferroceptor. However, it is not all that simple to make an outside aerial. You should never climb about on the roof, or make holes in windows for the aerial lead without the express permission of you parents, and in fact we do not really consider this work for young people at all.
We should like to mention two other points concerning this. The aerial may not be connected directly to the chimney, but should be insulated from it. Special insulators are available for this purpose. Also, if you join any of the aerial wires, the joint should be soldered. It is in fact better to use one continuous wire, in which there are no joints at all.
If you use an outside aerial, it is highly advisable to use an earth lead too. By "earth" we mean the ground, and not just a bit of earth in a plant pot.
The water-mains pipes can form an excellent earth lead if they are metal. These pipes run through the ground for long distances, and make excellent contact with the earth. It is thus sufficient to connect your earth lead to a water pipe. Special clamps can be bought for this purpose. Any paint and rust which may be present at the spot where you want to connect the lead must be removed. This kit does not contain any material for the earth lead.
On the mounting card C1, it shows how the outside aerial and earth have to be connected.

VHF aerials

What is said here about outside aerials applies only to medium wave and shortwave reception. As our circuit C2 is intended for the reception of V(ery) H(igh) F(requency) signals our aerial requirements are somewhat different. The VHF wave range comprises the wave-

lengths on which television and FM broadcast stations work, and covers wavelengths from 10 m to 1 m (30 million to 300 million cycles/sec.) by international agreement. The elaborate structures that we see on the rooves of our homes today are directional aerials, and these are not so good for general reception as they are directed to one transmitter in particular.

A dipole aerial consists of two wires of equal length that are placed in a line. The adjacent ends of both wires are connected to the receiver by twin cable. In fact we can make such a dipole aerial quite simply by splitting up part of the twin cable. The place where the splitting begins can be fixed by winding a piece of cord around the line. If we want to keep it simple and are content with the reception of strong and medium signals we can make the aerial out of a piece of plastic mains lead about 10 feet long. For better reception we must erect our aerial on the roof or in the attic and in this case it is better to use special aerial cable (240 Ω or 300 Ω twin-lead), which is available in most electrical shops. Inside the house the aerial can be fixed to a wooden stick by means of cord or tacks. On the roof it is advisable to use insulators of glass or porcelain if available. If not, plastic insulation can be used. Dipole aerials have one annoying property: they must be cut to lengths according to the wavelength (or frequency) that we want to receive. The length of the split-up part must be somewhat less than half the wavelength. In the description of circuit C2 you will find a table that gives the proper aerial length for various frequencies.
The lowest frequency used in circuit C2 is about 28 MHz (11 metres). Here the proper length would be about 15 feet which is too much to be practical for indoor use.
It is better here to use the old system with earth connection and to take a quarter wavelength of wire (about $7\frac{1}{2}$ feet) as an aerial.

Trawler band

The Broadcast transmitters work on the Medium Wave, that is to say on wavelengths roughly between 190 and 600 m. There are also a number of interesting transmitters on the shorter wave lengths as well, such as on what is called the trawler band, which is between 160 and 60 m. To receive these you need another coil. This one you have to make yourself out of insulated wire. You need to wind 28 turns as close together as you can around the ferroxcube rod. First of all, naturally, you must take the Medium Wave coil off the rod.
Next to the trawler band coil add two more windings of insulated wire. The numbers of fig. 23 (page 21) correspond with the numbers of the MW-coil in circuit C1. Connect the wires of the coils with the same connection points to which the MW-coil was originally connected. Should you get a whistle, then try reversing wires 3 and 4. If you do not live close to the coast, an outside aerial will probably be necessary. Once everything is ready, turn the knob of the tuning capacitor very carefully and if all is well and you are not too far away from a transmitter, you can hear whether a fisherman has had a good catch and all sorts of interesting reports.

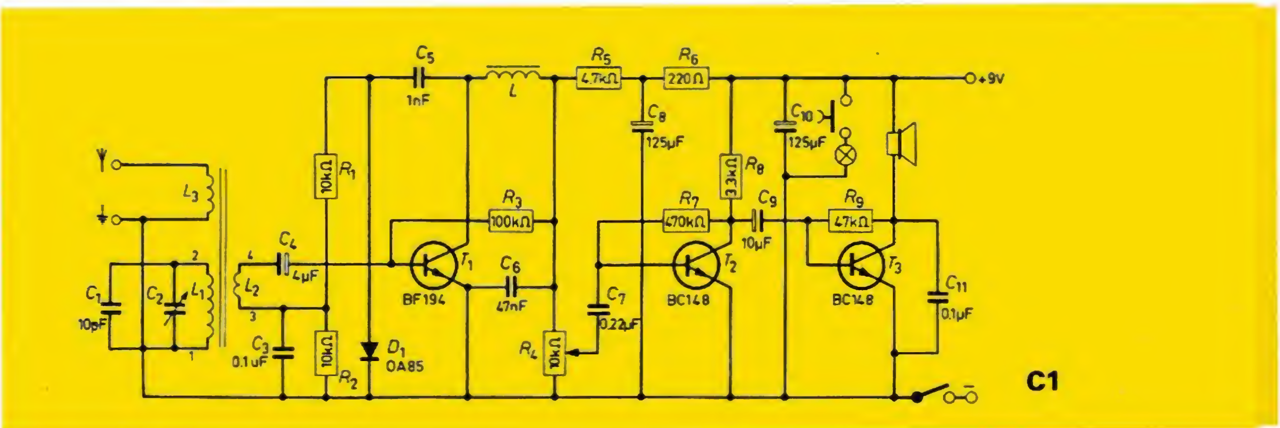
C1 Three transistor MW reflex receiver

The "reflex" principle means that one amplifier stage is used twice. This can never be the same signal because the circuit would oscillate. Mostly, two signals are handled that differ so much in frequency, that they can be separated easily. e.g. a modulated carrier with a frequency of 500 kc/s and a low frequency signal of less than 15 kc/s.
In this case it is necessary that the HF and the LF circuit do not influence each others signals. Moreover the HF and LF-signal have to be separated after the amplifier stage. In this circuit the transistor T1 acts as a reflex amplifier stage. We start at the moment that both signals arrive at

the base of the transistor T1. Both signals appear amplified at the collector of T1. The HF-signal is stopped by the choke and goes via C5 to the detector. The detected signal passes via the filter C3, R1, R3 the coupling coil L2 and the capacitor C4 to the base of transistor T1. The LF signal at the collector is stopped by the capacitor C5 and goes via the choke to the LF amplifier.
The HF-signal from the aerial appears between the top of the coupling coil and earth (the capacitor C3 is no obstruction for a HF signal) and is fed via C4 to the base of T1. We have now closed the circle. The coupling coil L3, 5 turns of insulated wire around the ferrite rod, can be used for connecting an outside aerial. It is then possible to receive weak signals. It will also be necessary to use an earth connection.
Because of its rather poor selectivity it is not possible to receive weak transmitters in the neighbourhood of strong ones.

C2 Super regenerative receiver

This circuit is not so easy. You will have to mount and trim very carefully. Mounting is done on the underside of the mounting plate to keep the connection wires as short as possible. (thus the mounting card is on the underside of the mounting plate)
Selectivity and sensitivity are best when the potentiometer is turned to a point where the apparatus just gives noise.
With this circuit you can receive various frequency bands. Therefore you must exchange L1, C2, C3 and C4 (see table 3). L1 always has 2 or 3 windings. Now you have to make the coils as shown in fig. 22. For a diameter of 10 mm use the ferroxcube rod, for 16 mm use a penlite battery. The windings that are coiled close together must be separated until the coil reaches the proper length (1).
This receiver has a HF-part and a normal 2-stage amplifier. In the HF-part we find a tuning circuit consisting of L2, C1, C2 and C3.
This is a rather complicated circuit, because at high frequencies, the waveband has to be very narrow to allow tuning to a particular station. A waveband of wider coverage would make tuning impossible, as a small movement of the tuning capacitor would give a very large change in frequency. Another point of complication is that the total capacity of the circuit must not become too large. The feed-back via the capacitor C4 causes the transistor T1 to oscillate. The value of C4 has to change for different frequency ranges. The HF signal from the aerial is fed to the oscillator, which acts as the super regenerative detector. It oscillates so strongly that it cannot handle its own signal and stops abruptly. After regaining its breath it starts again, and is also forced to stop again. The sequence of starting and stopping is so fast that we cannot hear it (about 50,000 times a second). We call this frequency the "quench frequency". This frequency also appears at the output of



C1

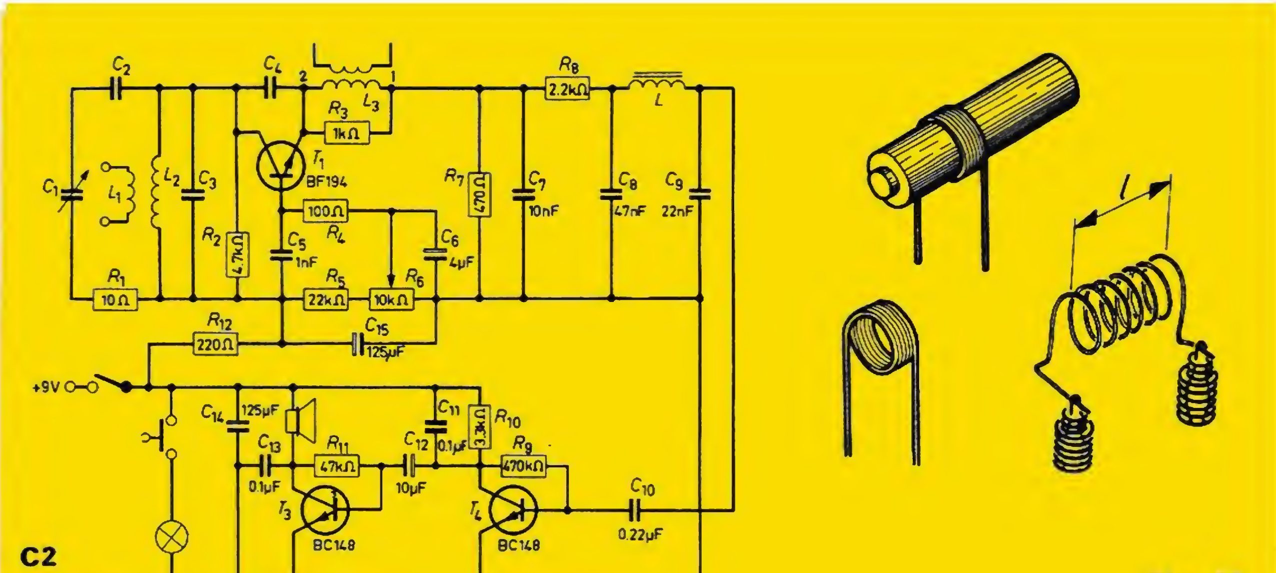


Fig. 22

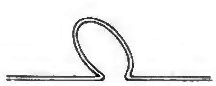
the detector. To stop the LF amplifier being overloaded, the quench signal has to pass the filter R8, C8, L4, C9. The DC-current flowing through the oscillator changes when oscillating begins to a different magnitude. As the oscillator stops and starts at high frequency we see that the DC current varies with the amount of time that it is oscillating. This oscillation time is, in its turn, influenced by the magnitude of the aerial signal.

A modulated aerial signal varies in magnitude. These variations, called modulation, cause variation of the DC-current through the oscillator. By means of the coupling capacitor C10 these variations, in other words, the LF signal, are fed to the LF-amplifier. L3 is a choke coil for the VHF-signal, and we use the aerial coil from the kit for this purpose. The grey and green wires of the coupling coil which are not used, are threaded through the holes of the mounting plate so that they cannot interfere with the wiring of the circuit and cause a short circuit (fig. 23).

Table 3

Frequency	Coil diameter	Number of windings	Length of coil	C2	C3	C4
26– 31 MHz	16	10	20	22pF	10pF	47pF
80–100 MHz	10	3	8	22pF	10pF	10pF
115–135 MHz	16	1*	–	22pF	10pF	10pF

* pulled out to a half-circle



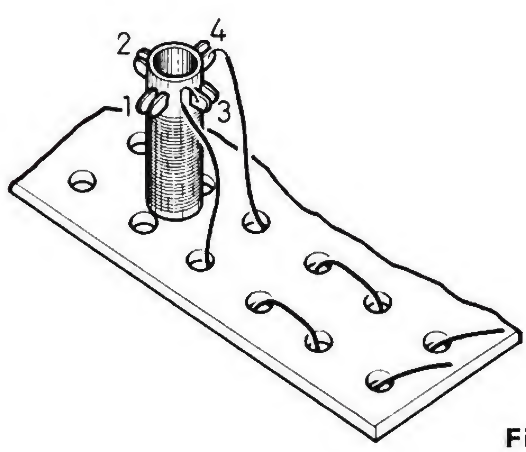


Fig. 23

D. ELECTRONIC SIGNALLING

In this chapter you will find many circuits in which a combination of two transistors act as an on-off switch. In fact such a set-up was used in circuit B3, but now we will try to explain the different switching circuits that we are going to use.
In the preceding circuits we have seen transistors act as linear amplifiers. The collector current changes in proportion to variations in the drive signal at the base. Now we are going to deal with switching circuits in which transistors either draw a fixed current that is determined by the rest of the circuit, or no current at all. When current is flowing, there is practically no voltage across the transistor. When the transistor is cut off (no current) there is a considerable voltage across it.
You can see from this description that the transistor acts just like an ordinary switch. When we have a battery, a bulb and a switch connected in series, exactly the same is happening. When the switch is "on" a current flows through it, the strength of which is determined by the bulb and the battery voltage. When the switch is "off" the voltage across it equals the battery-voltage.
Switching circuits such as we are going to describe now are often used in modern electronic calculating machines or computers.
The switching circuits have two transistors, one of which is in the "on" position while the other one is "off". The transistor that is "on" keeps the other one in the "off" position and vice versa.
The first circuit (fig. 24) we are speaking about is called "Schmidt-trigger". It is switched over and held in the desired position by a voltage that is applied to it from an outside source. The switch-over takes place at a certain input level. When the input voltage at A is gradually increased at first nothing happens. T1 is "off" and T2 is "on". When the critical input voltage is reached the situation is suddenly reversed. T1 is "on" and T2 is "off". At this moment the output voltage jumps from e.g. IV to 9V, (if the output connection B is not connected to a load). If a load is connected, the output voltage will change to a value that is somewhat lower, depending on the load. When the controlling voltage on the input is gradually decreased the output voltage falls back suddenly to its original value when the critical voltage level is passed again.

The second circuit (fig. 25) bears the characteristic name "flip-flop circuit". It functions in about the same way as the "Schmidt-trigger", but it holds itself in position with any input voltage.
An input signal is applied only to switch it over. This input signal can consist of a slowly changing voltage pulse that may have different shapes. Such a pulse can be applied through a capacitor.
A positive voltage on the connections marked A causes T1 to conduct and thus T2 to be cut off.
The flip-flop circuit can be switched back by a negative voltage on the input A but there are also other possibilities. A positive voltage on the base of T2 will have the same effect.
As a flip-flop circuit remains in any of two positions until a new signal is received

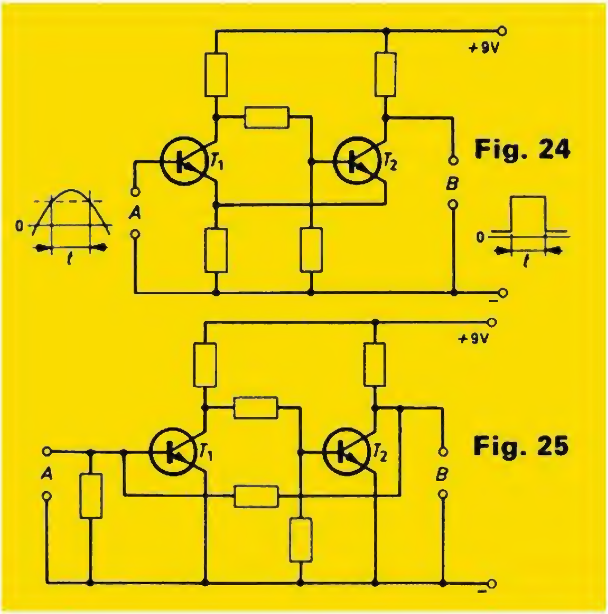


Fig. 24

Fig. 25

it can function as a memory that remembers the signal last given.

The third switching circuit (fig. 26) is related to the second one (fig. 25). It cannot stay in "on" or "off" position but switches continuously on and off, with intervals that depend on the values of the capacitors and the resistors in the circuit. It is called a multivibrator and can switch so fast that it produces a tone-frequency too high to be heard.
Such a free-running switching circuit can be considered as a frequency-generator. The difference is that it produces a square wave voltage instead of a sinusoidal voltage as normal oscillators do. As this circuit has its own switching sequence it needs no commanding signal.

It is possible to make a fourth circuit by combining a flip-flop and a multivibrator. (fig. 27) In this circuit T2 is normally conducting and T1 is cut off. A positive voltage on the input connections will reverse those conditions. This reversal cannot remain, as the coupling capacitor between T1 and T2 can pass only charges of short duration. After a brief period the circuit falls back automatically to its original position.
The time depends on the value of the base resistor and capacitor of T2 and can vary from a fraction of a millisecond to many seconds.

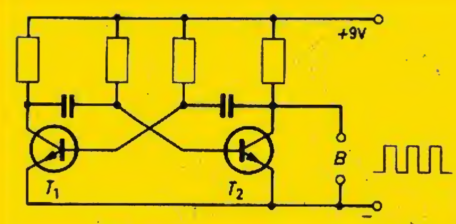


Fig. 26

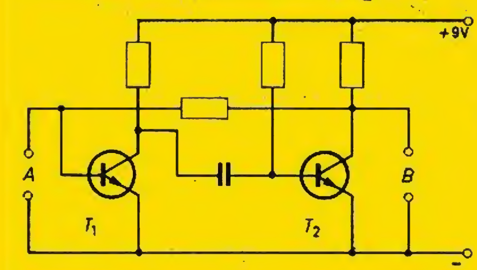
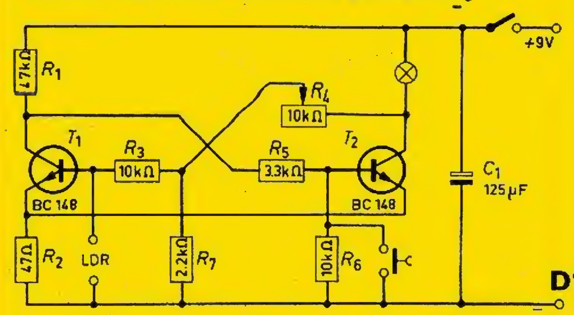
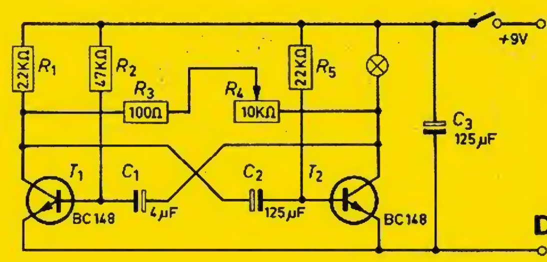


Fig. 27



D1



D2

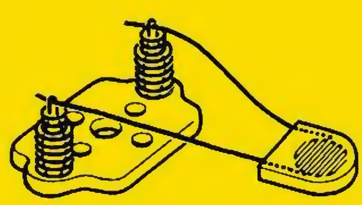


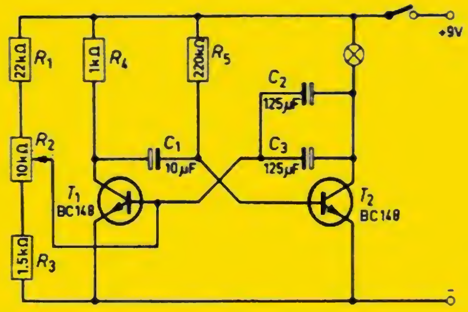
Fig. 28

D1 Tell-tale light

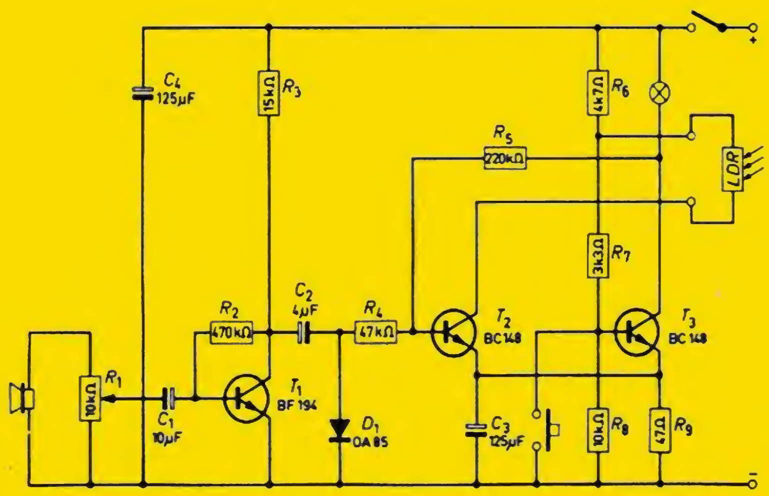
In this flip-flop circuit the switching-over is caused by a change in resistance value of a LDR. When light falls on the LDR T1 is cut off, T2 becomes conducting and the lamp lights up.
When the LDR is no longer illuminated, the circuit does not switch back but stays as it is. It can be switched back by pressing the key that cuts off T2. The variable resistor R4 determines the illumination level at which switching over occurs. Fig. 28 shows how the LDR can be attached to a cable. With this experiment it is possible to determine whether something has been moved or somebody has been in the room.

D2 Traffic beacon with adjustable frequency

A slow-running multivibrator makes the lamp go on and off. The switching frequency can be changed by the variable resistor, R4.



D3



D4

D3 Flashing light with adjustable frequency

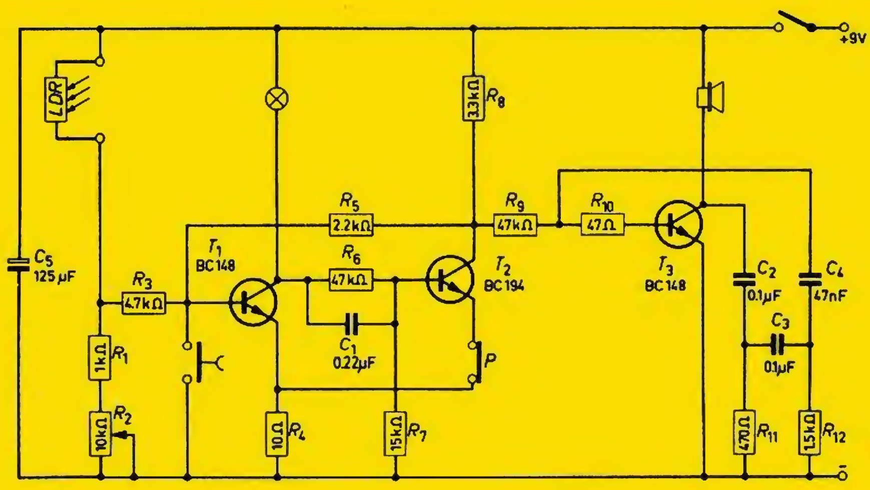
This circuit is much the same as D2. The lamp glows for only a fraction of a second, while the time that it is extinguished is much longer. When used as a warning light this circuit does not consume much current. The time during which the lamp does not glow can be varied by the potentiometer R2, the glowing time remains constant.

D4 Acoustic relay (works also on light interception)

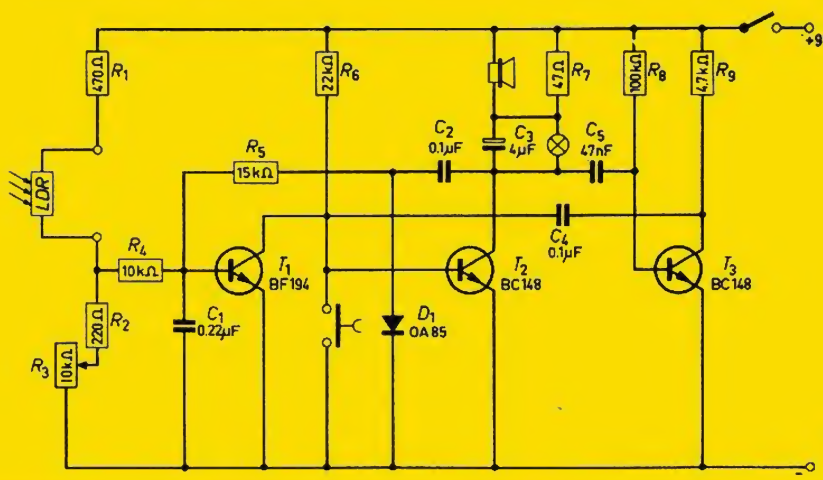
T2 and T3 are connected in a flip-flop circuit.
In the collector circuit of T2 a LDR, has been included.
When illuminated the resistance of the LDR is so low, that it has no influence on the circuit. When the light is intercepted the resistance increases and the flip-flop circuit switches the lamp on.
This can also be accomplished by a negative voltage on the base of T2. This negative voltage is developed by a detector circuit, C2 and D1, that rectifies the output signal of T1.
In this way a sound, picked up by the loudspeaker can switch on a warning light. Pressing the key puts the circuit back in its starting position.

D5 Pilfering alarm

A bi-stable flip-flop circuit, T1 and T2, is switched over when the LDR decreases its resistance under illumination e.g. from



D5



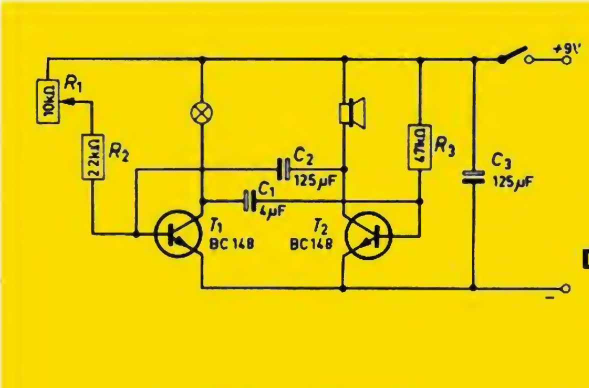
D6

a flash-lamp. The light intensity at which switching occurs is set by the potentiometer R2. In the dark, T1 is cut off and T2 is open. When the window-contact P, in the emitter of T2, is interrupted, the circuit also switches.

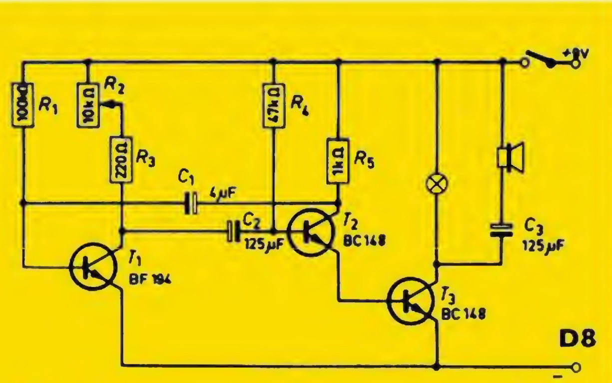
T3 is connected in an RC tone-generator circuit that starts oscillating when base-current begins to flow.
With T2 conducting no base-current is flowing through R9 and R10 as there is no collector-voltage on T2. When the flip-flop circuit switches over the collector-voltage of T2 rises several volts and T3 starts oscillating, giving a warning tone through the loudspeaker. This warning tone continues when the window is closed or the light is switched off, until the reset key is pressed.

D6 Burglar alarm

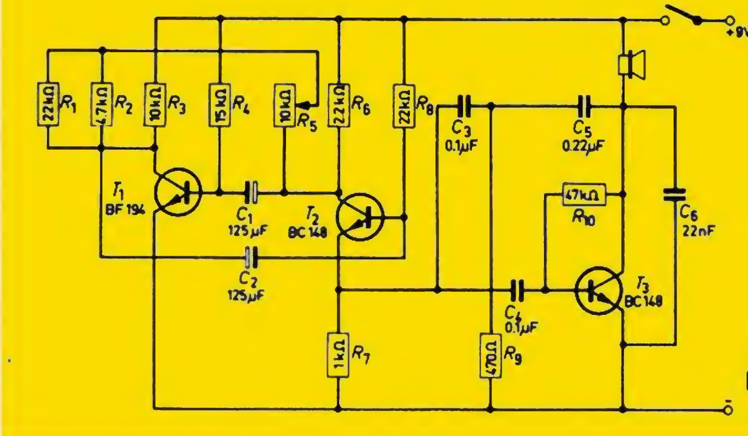
This apparatus resembles the preceding one in function but the circuit is quite different. Here the alarm goes off when light on the LDR is intercepted.
T2 and T3 are connected in a multivibrator circuit. The multivibrator is kept inactive by the conducting transistor T1 which shorts circuits the base of T2. This condition is maintained as long as T1 receives sufficient base-current through R1, the illuminated LDR and R4. When the light is interrupted the resistance of the LDR increases and the base-current of T1 drops. Therefore T1 no longer forms a short circuit on the base-circuit of T2 and the multivibrator starts oscillating. Now a negative voltage is developed by the rectifier D1 which keeps T1 cut-off



D7



D8



D9

even when light falls on the LDR again. Therefore the alarm stays on until the reset-key is pressed.

D7 Two transistor direction indicator

This circuit is rather similar to circuit D2. The loudspeaker is used as a collector resistor of T2. Therefore the switching of the collector current becomes audible as a series of clicks. The switching of the collector current of T1 becomes visible through the lamp. The switching frequency can be varied by the potentiometer.

D8 Three transistor direction indicator

The performance of this circuit is the same as that of D7. The only difference is that the multivibrator, with the transistors T1 and T2, does not incorporate the loudspeaker and the lamp. These are activated by a separate switching transistor T3 which is opened and closed by the multivibrator.

D9 Two-tone klaxon

This circuit produces a tone that jumps up and down in frequency. The RC-generator with transistor T1 contains a resistor R7 of 1000 Ohms. The generator gives a certain frequency. When the resistor R7 is changed the frequency of the generator will also change. When the transistor T2 of the multivibrator is conducting then R7 is in parallel with a part of the multivibrator. The overall resistance goes down and consequently the generator frequency goes up and down with the switching cycle of the multivibrator.

E ELECTRONIC MEASURING AND CONTROL

Measuring, is the determination of quantities, dimensions etc. You will know about the measurement of length, with a ruler, and of weight, with scales, these measurements being carried out by comparison with a know length or weight. With our measuring bridge E7 the same principle is applied to electrical quantities.

Many measurements are done by converting the dimensions or quantities that we want to know, into others. Scales that work with springs, convert weight into displacement. A thermometer converts a temperature rise into a volume increase of an amount of mercury.

In electronic measuring techniques, all kinds of quantities, dimensions etc. are converted into electrical voltages and currents, which can be applied and interpreted by electronic circuits. The measured value is then shown on a display unit, for instance a meter scale.

In electronic control systems the electrical voltages and currents are not only used to show measured values, but also to influence a control unit that maintains the measured property on a wanted value. As an example we can consider a machine that automatically manufactures carbon resistors, by depositing a thin layer of carbon on a tube of insulating material. The resistors, coming out of the machine, are measured automatically. The resistance value is converted into a voltage that is fed back to a control unit. Here it is compared with a standard voltage. The difference between the two voltages determines the amount of carbon that is deposited. If the resistance is too low, more carbon is applied on the insulating tube and vice versa. In this manner the resistance of the products is maintained at the desired value.

If we change the standard voltage in the control unit, the machine produces resistors of a different value.

In all control systems information about the results of the process is fed back to a point where these results can be influenced. Automatic control of processes always takes place in a closed loop, where a stream of information and a stream of results are coupled via an amplifier (A) head to tail by a measuring device (M) and a control unit (C) (fig. 29).

A simple example of such a closed-loop control circuit can be made with this kit. The aim of the circuit (fig. 30) is to make the lamp glow with a fixed intensity, independent of the battery voltage or other circumstances. The light of the lamp falls on the LDR and in order to ensure that no other light can interfere, we put the LDR in a cardboard tube that is blackened on the inside. If the amount of light tends to decrease, the resistance of the LDR increases. As a result of this the base voltage and the collector current of T1 will decrease. T3 will now receive more base current and thus its collector current will go up and restore the light intensity of the lamp to the wanted value. This value can be adjusted by turning the potentiometer R3. With the lamp connected to the + 9 V, we adjust the potentiometer so that a soft glow is obtained. Making use of the taps on the battery holder, we can now lower the battery voltage in steps of 1.5 V. The glow of the

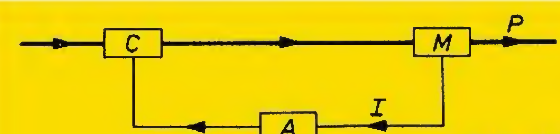


Fig. 29

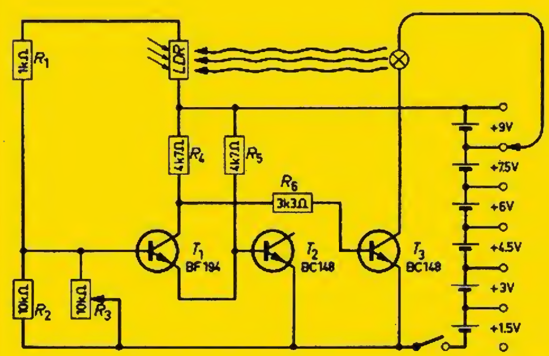


Fig. 30

lamp does not change, until we come to too low a voltage (3 V or 4.5 V); the controlling circuit maintains the light intensity on the pre-set value.
This result is based on the functioning of a controlling loop. To show this, we can open this loop and the easiest way to do this, is to intercept the light going to the LDR. We now again adjust the potentiometer for a soft glow and try different battery taps. The light intensity now changes with the battery voltage.
This test is not too easy to execute; we have to tamper somewhat with the amount of light that falls on the LDR and with the setting of the potentiometer, which is very critical. It is much easier to replace the LDR by a resistor of 47 k-Ohm, which is about the value it has when illuminated by the lamp.

E1 Automatic night light

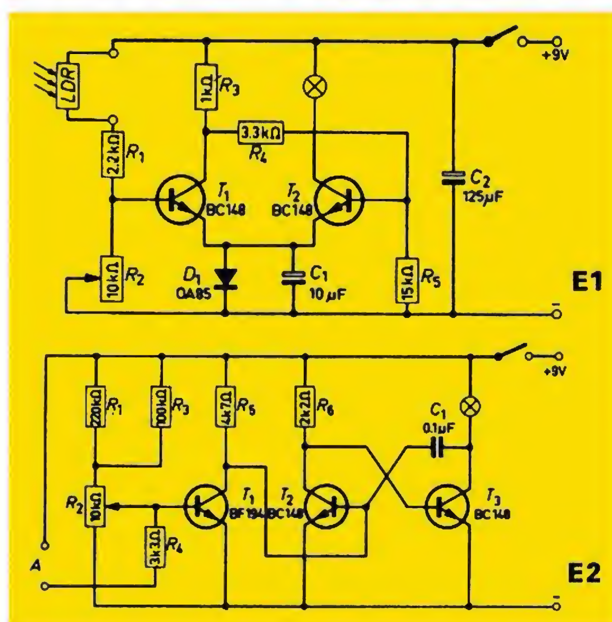
This circuit switches on a lamp when the illumination drops below a certain pre-set level, and off, when the illumination increases to a value above this level. The circuit consists of a Schmidt trigger with a voltage divider at the entrance. The potentiometer with which the level is set, is the lower part of this voltage divider. The other half consists of the LDR with a resistor R1 in series for protection of T1. The diode is used here as a common emitter resistor for the two transistors. This has been done because of the fact that the currents that flow through the two transistors are very different (3.5 mA against 50 mA).
With a normal emitter resistor this would result in emitter voltages of quite impractical values. We could use an emitter resistor of 47 Ohm for instance. The voltage on the emitter would be 2.3 V and 0.16 V. The diode will give voltages between 1 V and 2.5 V independent of the current, so much more constantly than a resistor.
We must stop the light of the lamp falling directly on the LDR, otherwise the circuit will keep switching on and off, and the lamp will flicker.

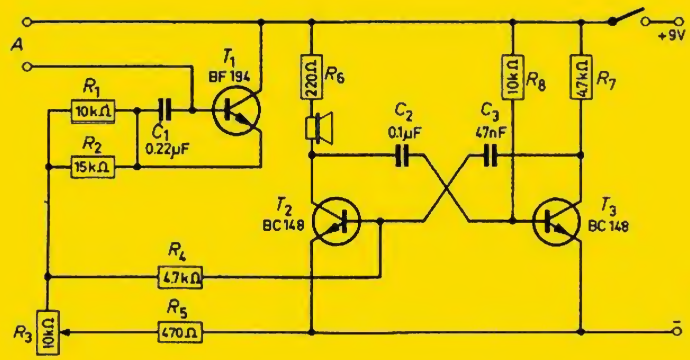
E2 Wetness indicator with indication light

This circuit makes a three-stage D.C. amplifier. A very small current (1 μA) arriving at the base of T1 causes an output current that is ample to make the lamp glow. This very small current is fed to the base by a voltage divider that is built up of several resistors R1, R2, R3, R4 and one resistance that is outside the set. For this you take a piece of paper to which you attach two bare wires close together. The wires must not touch each other. These two wires run to two of the input connections (A). When dry it has a very high resistance (for instance 10 M-Ohm); when damp or wet the resistance becomes much lower and then current is fed to the base of T1 and the lamp glows. The resistance, in this case the amount of moisture, at which this occurs can be changed by the potentiometer.

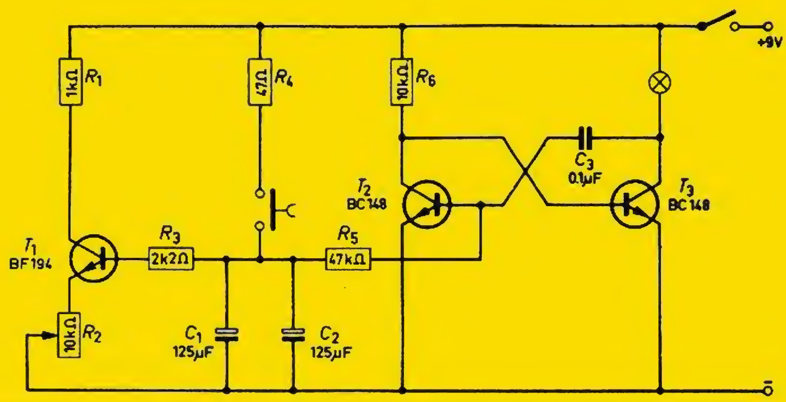
E3 Wetness indicator with sound signal

The transistors T2 and T3 are connected in a multi-vibrator circuit. This multi-vibrator does not oscillate because the voltage at the base of T2 is too low to permit this transistor to draw current. The base





E3



E4

voltage of T2 is determined by a rather complicated voltage divider, in the upper part of which we find T1. This transistor acts as a variable resistor, the value of which is influenced by its base current. The magnitude of this base current depends on the moisture-sensitive element that is connected to the input A (see E2). The resistance value (or dampness) at which the circuit starts oscillating, can be changed by the potentiometer.

E4 Time switch with indication light

The input current of a D.C. amplifier (T2, T3) is delivered by the charge of two electrolytic capacitors. As long as T2 draws current, T3 is blocked and the lamp does not glow. When the charge of the capacitors is nearly exhausted, the input current becomes too low to make T2 draw collector current, T3 opens and the lamp starts glowing. The time it takes to discharge the capacitors depends on the current that is drawn from them. Therefore, an extra discharge path is provided that can be regulated in order to influence the discharge time. This additional discharge current is drawn by the base of T2 and the magnitude is varied by the potentiometer that is connected as an emitter resistor. The extra discharge cannot be accomplished directly by the potentiometer, as the maximum value of 10 k-Ohm is too low to obtain a sufficiently long discharge time. The time switch is started by pressing the key, the electrolytic capacitors are then fully charged.

E5 Time switch with sound signal

Here again the time is measured by the discharge of two electrolytic capacitors. The difference is that the discharge time is not reduced by increasing the discharge current, but by bringing a smaller charge into the capacitors.
The discharge current flows into the base of T1. As long as this transistor draws current, T2 is blocked. When the capaci-

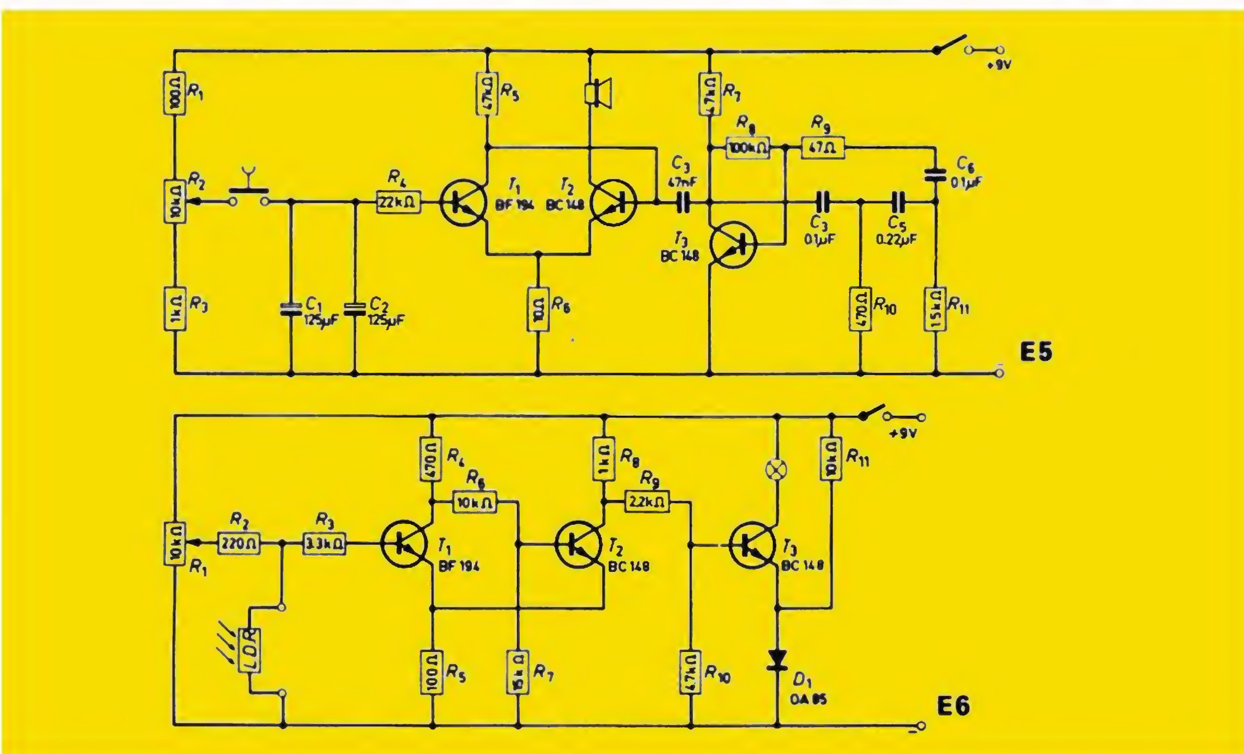
tors are nearly discharged, T1 cuts off and T2 opens. T3, acting as an RC tone generator, feeds an A.C. voltage into the base of T2. As soon as T2 opens, the tone generated by T3 and amplified by T2, is heard through the loudspeaker.

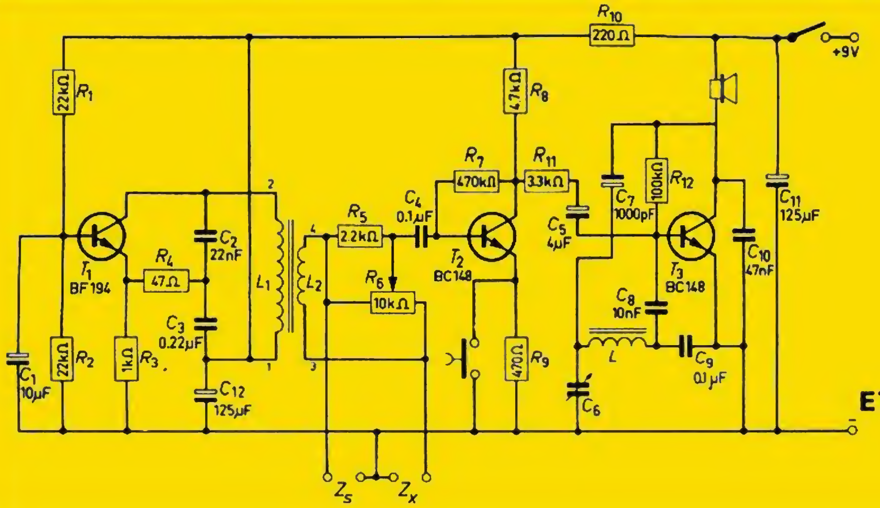
E6 Light meter with indication lamp

The transistors T1 and T2 are connected as a Schmidt-trigger. The base voltage of T1 comes from the tap of the potentiometer. The position of the potentiometer at which the Schmidt-trigger switches over depends on the amount of light that is falling on the LDR. This switch over is indicated by the lamp.
With T2 conducting, T3 must be cut off. However, the collector voltage of T2 can never drop to zero. Due to the voltage drop over the emitter resistor, R5, there will always be about 1 V on the collector. If the emitter of T3 were connected directly to the negative pole of the battery, this voltage would stop T3 being cut off completely.
The combination of the diode and the resistor R11 gives a blocking voltage of about 0.5 V on the emitter, and this stops T3 drawing current when T2 is conducting.
When the LDR is exposed to light, we can turn the potentiometer knob until the lamp starts glowing. The position of the knob gives an indication of the light intensity.

E7 Measuring bridge for resistors, coils and capacitors

With a measuring bridge we can compare the value of an unknown resistor, capacitor or coil with the value of a known one. We do this by means of a bridge circuit that can be considered as two voltage dividers connected in parallel. The potentiometer is one of those voltage dividers and the other one consists of, for instance, two resistors, of which one is known (R_s). and the other must be measured (R_x). Across the two voltage dividers a tone generator G is connected and the dividing points A and B (fig. 31) are interconnected by some kind of a voltage indicating device, for instance an earphone. If now the voltages at A and B are different, the





E7

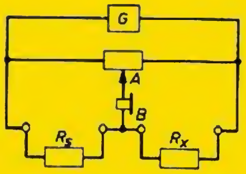


Fig. 31

earphone will produce sound. It is possible by turning the knob of the potentiometer to vary the voltage at A till it is equal to the voltage at B. The sound will then disappear.
At this moment the resistance ratio of the two voltage dividers is equal and when we have a scale indicating the dividing ratio of the potentiometer, we also know the ratio of the two resistors R_s and R_x. If we know the ratio of a known and an unknown resistor, we can estimate the value of the unknown one.
The same reasoning goes for two capacitors or two coils, but not for mixed configurations of the different kinds of components.

At the connecting clamps of the bridge we find the indications Z_s and Z_x. The letter Z stands for impedance.
Impedance is the resistance that is offered by a capacitance or inductance to the passing of alternating currents. For a coil this resistance increases with the inductance. For a capacitor the opposite is true; here the resistance decreases with an increasing capacitance or frequency. We must bear this in mind when we read on the scale of our measuring bridge the value of the impedance ratio. If the scale indicates that $Z_x = 2 \times Z_s$, this means for resistors $R_x = 2 \times R_s$. For coils $L_x = 2 \times L_s$, but for capacitors $C_x = \frac{1}{2} \times C_s$. L stands for the inductance of a coil.
If we now take a look at the circuit diagram E7, we see first of all the oscillator with T1 that delivers the measuring frequency to the bridge circuit. It is an LC oscillator working on a frequency of about 50 kHz. The voltage difference of the bridge circuit is amplified by T2 and fed to the final stage. If the amplified signal were applied to the loudspeaker as it is, the effect would be zero, as a frequency of 50 kHz is inaudible. Therefore, T3 works as an oscillator on a frequency that is slightly lower than that of the first oscillator. The frequency difference can be heard through the loudspeaker. The frequency of the second oscillator, and consequently the frequency difference, can be changed by the variable capacitor C6. The amplification of T2 increases when the key is depressed, thus short-circuiting the emitter resistor.
Using the bridge is very simple. After connecting a known component to the connections marked Z_s and an unknown but similar component to Z_x, we simply turn the dial to that position that gives minimum sound volume.
Then we depress the key and the sensitivity increases, which enables us to adjust the dial more accurately. As was said before, the reading of the dial now gives us the ratio between the values of the two components. Remember the reversal of ratio for capacitors.

ELECTRONIC CONTROL

The following models can be made, in conjunction with the Mechanical Engineer ME 1201. Most of the instructions you will find on the large drawings in the kit ME 1201. The data gives you only a few of the experimental possibilities there are. For instance, the switch for two forward and two reverse positions of model EM7 can also be mounted in the models EM5, EM8, EM9 and EM11.
NOTE: If the motor runs the wrong way round, change the connections to the motor and never to the battery, or you may damage the transistors.

EM1 Motor car

This car is the basis for a lot of the following models. In this case the motor has two forward speeds and two reverse. This model can be made with or without a motor and can have different types of switches, a switch under the steering-wheel or a switch between the sides. All these constructions you will find on the drawings concerned.

EM2 Car with two-tone klaxon

By pushing the push-button on the steering-wheel, two contacts are made, one after the other. Each contact will give a tone of a different pitch.

EM3 Car with electronic direction indicators

With the switch under the steering-wheel, the right or the left direction indicator can be switched on. The lamp goes on and off with a duration which can be varied with the potentiometer.

EM4 Car that stops when moving on to a dark floor area

This car stops automatically when the LDR travels over a dark floor area. This also happens when the car reaches the edge of a table. You can adjust this very accurately with the potentiometer. The strip with the LDR is mounted in front of the car, with the LDR below.

EM5 Car with automatically lighting head-lamps

The circuit is switched on with the switch under the steering-wheel. The lamps go on automatically when the car runs into a dark area. The light intensity at which this happens can be adjusted with the potentiometer.

EM6 Light-activated siren

The light falling on the LDR is interrupted by the vanes on the wheel at a certain frequency. This causes a variation of current through the LDR at the same frequency. This frequency is amplified and reproduced by the loudspeaker. The switch makes two contacts, one after the other. The first switches on the amplifier and the lamps, the second one the motor. The lamp-holder is held against the motor housing by means of a rubber band.

EM7 Car with stop light

The car stops automatically after a certain time, the brake light going on at the same time. The time from stop to stop can be regulated from three to five seconds with the potentiometer.

EM8 Car that reduces speed in the dark and lights head-lamps automatically

This car drives normally until it comes into the dark. The car slows down and switches on the head-lamps. The light intensity at which this occurs can be adjusted with the potentiometer.

EM9 Car that stops on a dark floor area and starts again automatically

As soon as this car reaches a dark floor area, the car stops for a moment. The stopping time can be adjusted by the potentiometer.

EM10 Level control

The two rods under this model can be put into a reservoir. When we fill this reservoir with a conductive liquid, for instance water from the tap, the motor is switched off when the water reaches a certain level. This level can be regulated with the potentiometer.

EM11 Adjustable maximum setting switch

The motor stops when the car is too heavily laden or hits something. The load at which this occurs can be regulated. To get the car running again, the points X and Y have to be connected for a moment.

EM12 Obstacle light

The lamps go on and off in turn. The tempo is adjustable with the potentiometer. When the potentiometer is switched off, one lamp stays alight, much longer than the other.

NOTES

NOTES

FINAL CHECK

Read the instructions for assembling each set thoroughly and see whether there are any special remarks on it, such as the connection of the aerial coil, morse key, etc.

When you have done everything stated in the general instructions and the instructions for assembling the sets, then the job is finished. First of all, check that you have not overlooked something. That is, ensure that:

- the correct components are in the correct place,
- you have not forgotten anything,
- the wires are not touching one another, where they should not be,
- all electrolytic capacitors are fitted properly with the positive end as marked.
- you have not connected any transistor the wrong way round.

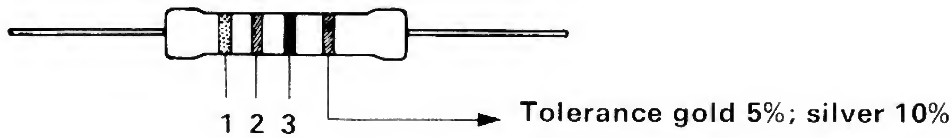
When you have checked all this, including the assembly instructions, then you can switch on. If you have made no mistakes then your set will work well. If it doesn't, read the section on "Checking for faults".

CHECKING FOR FAULTS

If a set does not work properly switch it off immediately and start with the following points:

1. Check the wiring. Compare it with the wiring diagram on the mounting board. Make certain that you have not forgotten any connection or any component. Look and see if the wires make proper contact in the wire terminals and that they do not touch one another where they should not.
2. Check that you have not confused the positive and negative poles of the battery and that the spring connections between the batteries have not been forgotten or have worked loose.
3. Check whether the transistors have been connected the right way (collector, base, emitter and eventually screen).
4. Check whether the diode has been connected in the correct direction.
5. Check whether the electrolytic capacitors are connected in the right direction, that is, with the groove (+) as printed on the wiring diagram.
6. Look at the colour code information given at the end of the book to make sure that you have used the correct resistors.
7. If necessary take a new battery to see whether the lamp is damaged.
   The circuits only work with a lamp as provided (6 volt at 0.05 Amp). Any other voltage or current rating will not function properly.
8. Check that your batteries are not empty.

COLOURCODE FOR RESISTORS AND CAPACITORS



Colour	1st band (1st digit)	2nd band (2nd digit)	3rd band (factor)
black	0	0	x 1
brown	1	1	x 10
red	2	2	x 100
orange	3	3	x 1000
yellow	4	4	x 10,000
green	5	5	x 100,000
blue	6	6	x 1,000,000
violet	7	7	
grey	8	8	
white	9	9	

Resistors

10 ohm	brown black black
47 ohm	yellow violet black
100 ohm	brown black brown
220 ohm	red red brown
470 ohm	yellow violet brown
1000 ohm	brown black red
1500 ohm	brown green red
2200 ohm	red red red
3300 ohm	orange orange red
4700 ohm	yellow violet red
10.000 ohm	brown black orange
15.000 ohm	brown green orange
22.000 ohm	red red orange
47.000 ohm	yellow violet orange
100.000 ohm	brown black yellow
220.000 ohm	red red yellow
470.000 ohm	yellow violet yellow

Capacitors

10 pF	brown black black
22 pF	red red black
47 pF	yellow violet black
1000 pF	brown black red
10.000 pF	brown black orange

PHILIPS

3122 106 19661

Printed in Holland

HOW DO ELECTRONICS WORK

Engineers and technicians of our great laboratories have designed all the circuits of this electronic engineering kit. They have used all their skills to construct experiments, just as they do when they work on radio or radar, on electronic controls or television.
The field of applications of electronics is vast and for that reason the demand for designers and technicians is steadily growing. Perhaps the pleasure that you will derive from your Electronic Engineering Kits will encourage you to think of making technology your career.
At a later stage in your life, you will realise how many useful things you learn't when you were experimenting with your Kit. We wish you many hours of enjoyment.

ATOMS

Everything in nature is made up of atoms These atoms consist of a nucleus with a number of electrons round it. This can be compared with the solar system. In our solar system the sun is the nucleus and the planets revolve around it.
The tiniest piece of matter still detectable as such, consists of millions of atoms. In nature, substances differ one from another in regard to the composition of

ANDRE MARIE AMPERE (1776 - 1836)

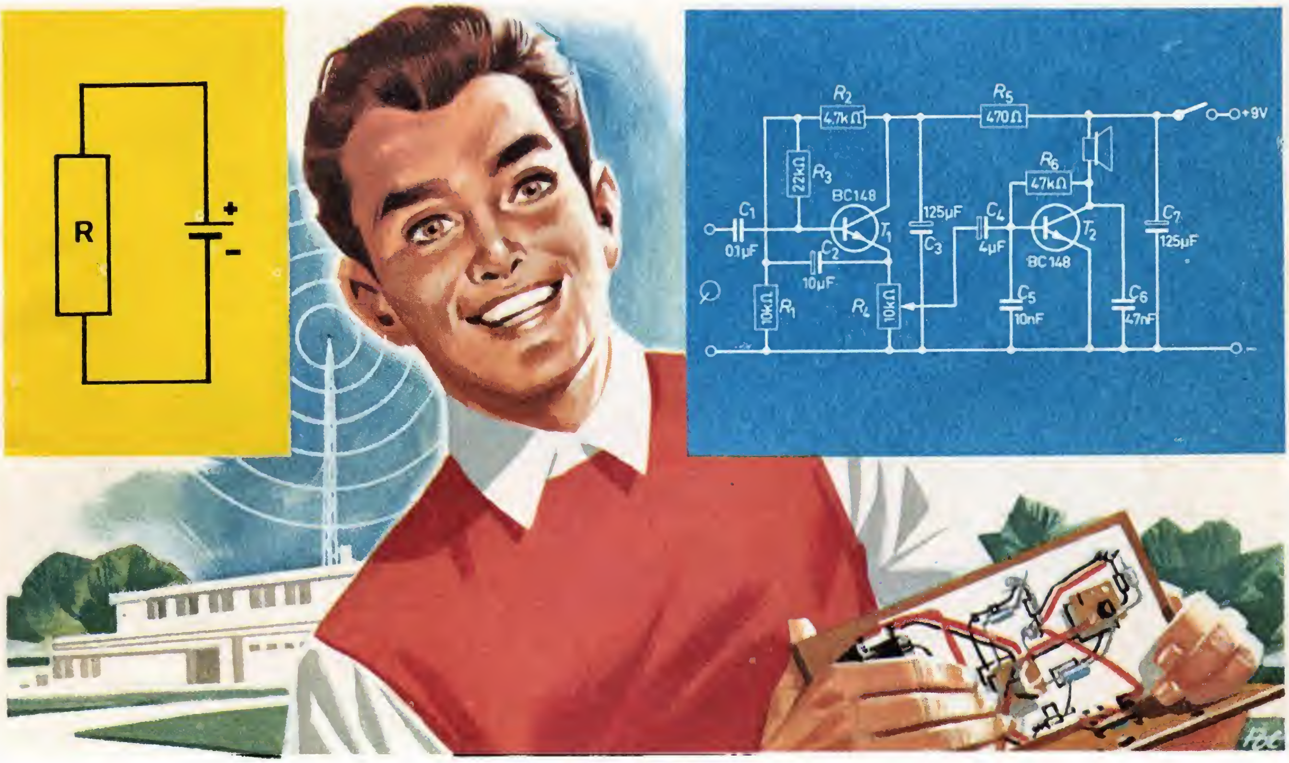
ALESSANDRO VOLTA (1745 - 1827)

the nucleus and the number of electrons revolving around it.
Hydrogen is the substance with the simplest atom; only one electron revolves round the nucleus of the hydrogen atom. that of helium, has two electrons.
As for the copper atom, this has 29 revolving electrons, not all of which are at the same distance from the nucleus. The last of the 29 is far away from the nucleus, almost free from the others. The force that holds it in its solar system is not as strong as for the other electrons and so, it is able to slip from one copper atom to another. It is called a free electron. Since even a tiny bit of copper contains millions and millions of atoms, it also contains millions and millions of free electrons. Electrons carry a negative electric charge and a movement of electrons is called an electric current. Electrons can move easily through copper wire, and so copper is a good conductor

BIG AND LITTLE CURRENTS

When you turn on a tap, water begins to flow through a pipe. When you turn on the switch of an electric light, electrons stream through the wiring in enormous numbers, for when you switch on a large lamp, 6.3 million times a million times a million electrons flow through the lamp each second. It is very hard to work with

such a number and that is why a current of 6.3 million times a million times a million electrons per second is simply called a current of 1 ampere.
This can be written in an even shorter form as 1A. In electronics we are usually more sparing of electrons than in what we call the mains power supply. Here much smaller currents than 1 ampere (1A) are used, in fact 1000 or a million times smaller. In order to make it easier to talk about these little currents, the thousandth part of an ampere has been called a milli-ampere, shortened to mA and the millionth part of an ampere is called a micro-ampere shortened to μA.



RESISTANCE

You know very well that water does not run through the pipes of the water system of its own accord. It has to be pumped through, because the water meets with resistance in its path through the pipes. Electric currents meet with resistance when they flow through the copper wires of a circuit, in just the same way.

In both cases a long supply system offers more resistance to the current than a short one and a narrow system offers more resistance than a broad one. In the case of water pipes, the sort of material of which they are made does not affect the flow. In electric wires it is more complicated, because if these are not made of a good conductor, like copper, then the current does not flow easily. For instance, iron has a greater electrical resistance than copper. The unit of electrical resistance is the ohm also written in symbol form as Ω.
A copper wire 200 yards in length and 1/12 inch in thicknes has a resistance of 1 ohm. A resistance of 1000 ohms is called 1 kilo ohm shortened to kΩ and one million ohm is called 1 megohm, shortened to MΩ. A resistance of 500,000 ohms can thus be called 500,000 ohms or 500 kΩ or 0.5 MΩ, whichever way is best for the purpose.

VOLTAGE

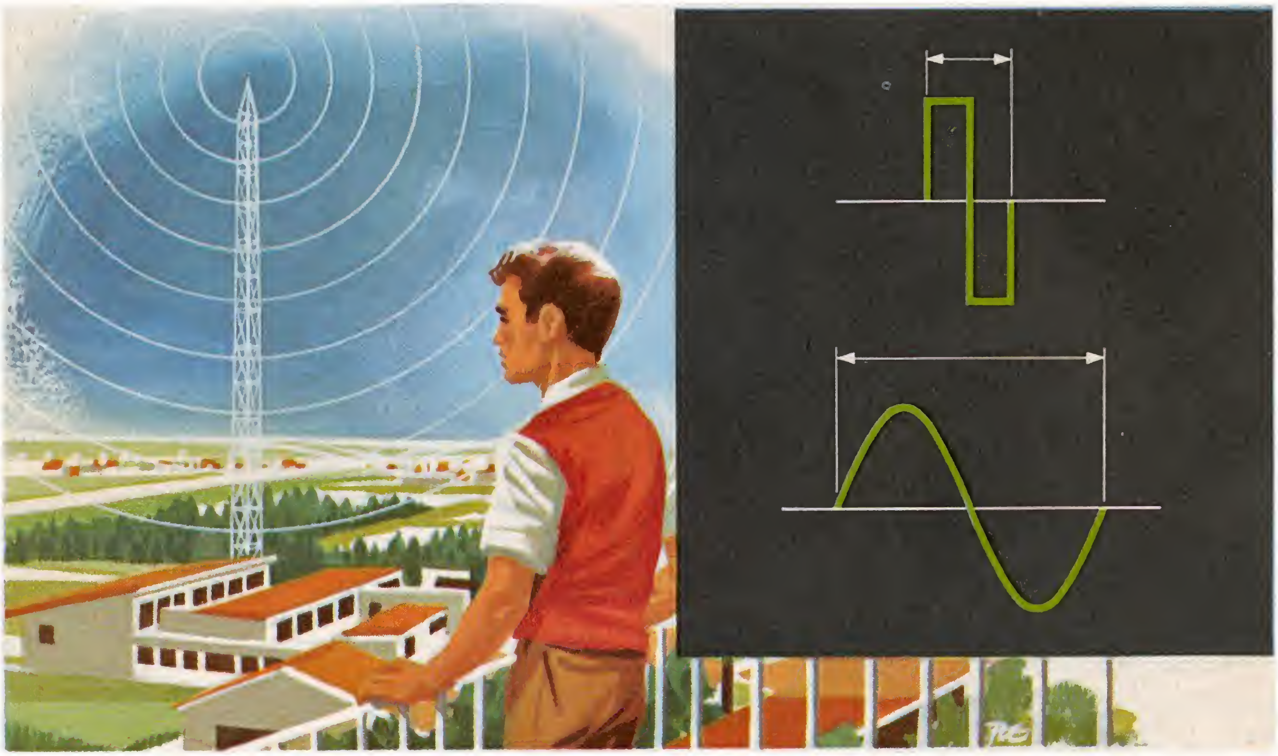
Water will not flow through pipes on its own. There always has to be a force to

send it through the pipes. Similarly an electric current requires a force, a force which we call voltage. Voltage can be obtained from a battery and the unit of voltage is called a volt. If you have a wire with a resistance of 1 ohm and you connect it to a battery with a voltage of 1 volt, then a current of 1 ampere flows through the wire. In electronics we can have voltages far greater than one volt and also others which are much smaller. For instance, the picture tube of a television receiver works with 18,000 volts. In this case we can also speak of 18 kilo volts (kilo = 1000), shortened to 18 kV. But in a radio receiver we also come across voltages of 1/1000 volt and 1/1,000,000 volt. These are called millivolt, and microvolt, shortened to mV and μV respectively.

The batteries we use for our electronic experiments have a voltage of $1\frac{1}{2}$ volts. However, if you put them in the battery-holder, they are connected as we say "in series". In that case the voltage from the batteryholder is 6 times $1\frac{1}{2}$ volts giving 9 volts. Of course you can use any 9 V D.C. supply. The words ampere, ohm and volt are derived from the names of famous scientists.

SYMBOLS AND DIAGRAMS

In electronics, we use components which



are connected to one another by means of copper wire. Circuit diagrams show us how the components are joined together theoretically. They do this by means of symbols and you will find these in the first part of the book. In the final chapter you will find diagrams relating to the circuits you can make with this kit.

PLUS OR MINUS?

On the symbol for the battery you will see a plus sign and a minus sign. These show the direction in which the current flows. But pay attention now: The agreement to do this was made before we knew of the existence of electrons. One side of the battery was called plus and it was said that the current flowed from plus to minus.

It was only later, that someone discovered that the electrons actually move in the opposite direction, that is, from the — to +. We should not laugh at our forefathers too much over this. They just had not sufficient information at the time.

A battery is, as it were, a little box, in which there are an enormous number of electrons. The electrons flow from the minus side across the resistor along the connecting wire to the plus side of the battery.

When the chemicals in the battery which generate the voltage have lost their

strength, the battery is discharged, and must be replaced by a new one.
The number of hours you can use a battery depends on the size of the battery, the strength of the current that is taken from it, and the time that it is in use.

ALTERNATING CURRENT

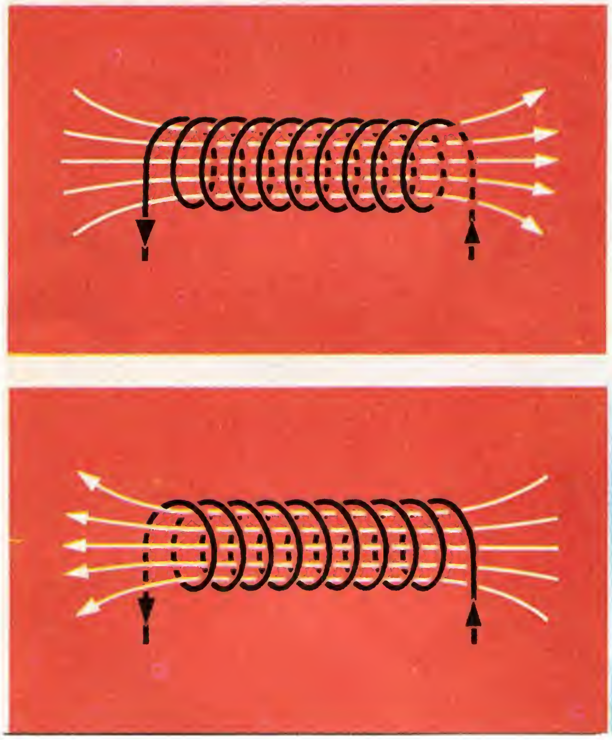
Until now we have considered only a current flowing in one direction. This is always the case in the water supply. In electricity it can be different. Here electrons can flow through the wire in one direction for a time, and then in the opposite direction and then once again in the first direction, and so on. If the water in the pipes behaved like that, very little would come out of the tap. However, electricity does not need to come out of the wiring, to be useful. In order to realise this let us learn from primitive man.
He could make fire, by rotating a stick very quickly in a block of wood. The friction caused heat and, if the heat was enough, the stick would start to smoulder. Friction means overcoming resistance. When you rub your hands, they get warm because one hand moves across the other and meets resistance. When an electric current flows through a wire, a resistance also has to be overcome. This makes the wire warm, regardless of whether the electrons move from left to right, from right to left, or to and fro. The strength of the current and the magnitude of the resistance determine how much heat is developed, irrespective of whether it is "direct current" (DC) or "alternating current" (AC). Examples of heat development by means of electric current are quite familiar to you e.g. the electric fire and the incandescent lamp.
Alternating current does, however, have other special advantages over direct current which we shall see in a moment.

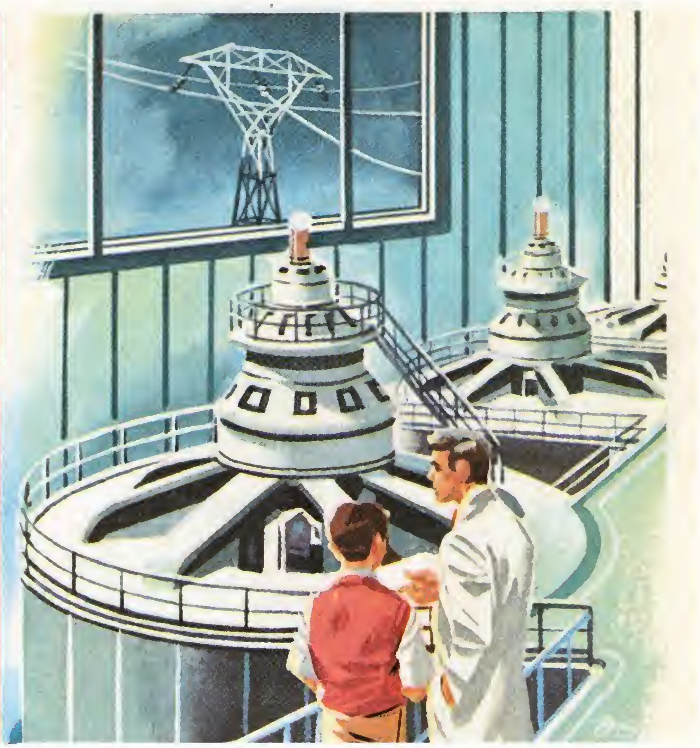
Alternating current is obtained from our mains sockets. Do not tamper with the mains as these voltages are more than enough to cause a fatal accident. The batteries we use give direct current, the voltage of which is enough to work the sets we are going to build, but fortunately

much too small to be able to cause accidents.

FREQUENCY

We need to know a bit more about alternating current than the number of amps. For instance we have to know the speed at which the current moves to and fro. Just imagine that the current moves from



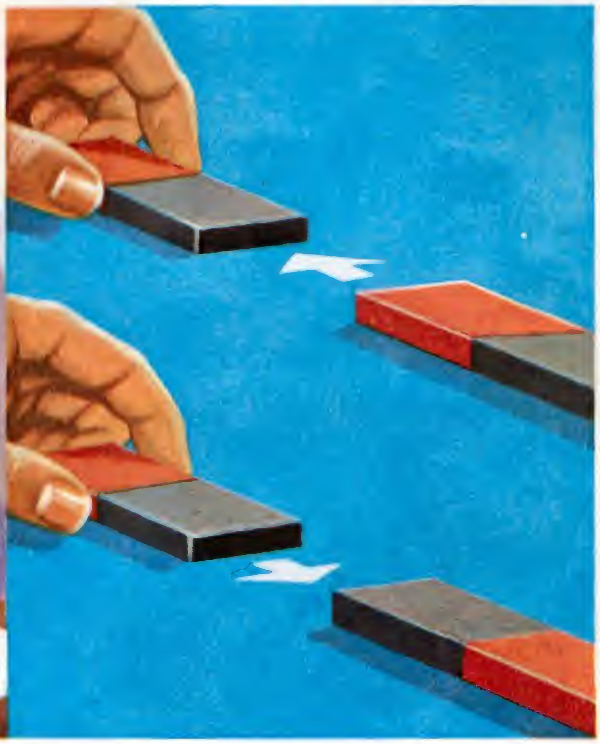


the top to the bottom for half a second and then for another 0.5 second from the bottom to the top. etc., that is, once up and down every second.
This once up and down or to and fro is called a "cycle" of the alternating current (and alternating voltage). The number of cycles per second is called the "frequency". In this example the frequency is thus 1 cycle per second. The voltage of the mains supply socket has a frequency of 50 or 60 cycles per second. Instead of writing cycles per second we can shorten it to c/s. or Hz (shortened from the name Hertz, also a scientist).
The power that our mains supply is able to deliver comes from giant rotating generators driven by steam or water turbines. The frequencies used in electronics are mostly much higher.
Many broadcasing stations work at frequencies of millions of c/s. For the sake of convenience, we speak of kilocycles per second (= 1000 c/s), shortened to kc/s (kHz) or megacycles per second (= 1,000,000 c/s) shortened to Mc/s (MHz). In reality an alternating current usually does not work by fits and starts but more gradually. It begins modestly in one direction, increases, and then decreases gradually, changes direction and so on. The horizontal line represents zero value. You can see that the current, or voltage, moves in two directions with respect to zero.

COILS

Alternating current goes through wires and resistors in just the same way as direct current. But when we wind a wire into a coil, we notice a difference. A coil offers more resistance to alternating current than it does to direct current.

The higher the frequency the greater the difficulty in flowing through a coil.
How does this come about? When a current passes through a coil a magnetic field is created similar to that around an ordinary bar magnet. A coil like this will therefore attract iron filings and a compass needle.
When a coil lies close to a bar magnet, no voltage is generated in it which can cause a current to flow, just as a stationary windmill will not generate wind. But this "no" is not final; which is just as well because otherwise radio, television and various other things would be impossible.
What really is important, is that if we move the magnet, a voltage is in fact generated in the coil. A magnetic field moving along a coil generates voltage in the coil. When a current flows through a coil a magnetic field is generated. When the current is reversed in its direction, the magnetic field also changes direction. The magnetic field thus varies and generates a voltage in the coil.
Now where does all this lead to? Let us pass an alternating current through the coil. This AC will produce an alternating magnetic field which will in turn produce an alternating voltage. So far so good. But what next? Will this new voltage help the old one to send a current through the coil or oppose it? Fortunately the new voltage opposes the old one, for if it were the other way round the current woud get bigger and bigger and bigger. As it is, however, the so called induced voltage works against the applied voltage and will thus cause the current to be smaller. It is the same as increasing the resistance.



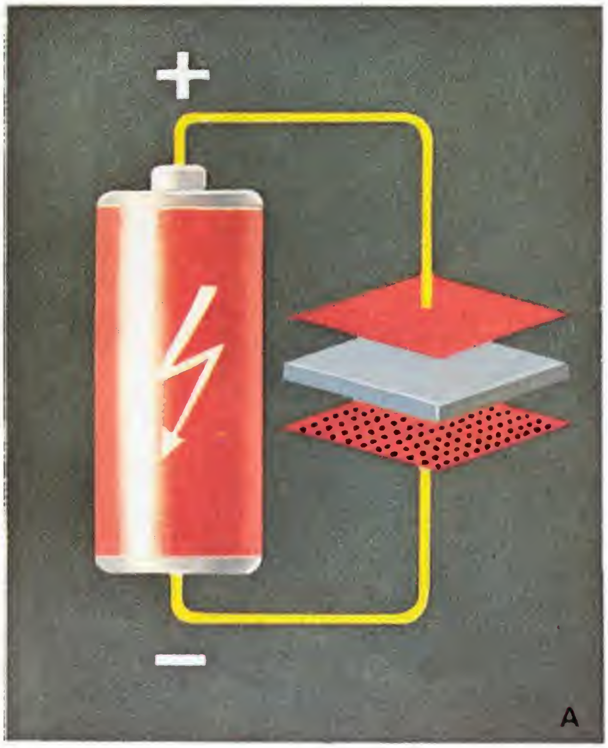
Now the higher the frequency of the alternating current, the more rapidly the current changes its direction and the greater is the counter voltage. As a result the current decreases while the resistance of the coil increases. Of course, had we applied a steady DC source there would be no induced voltage once the current had begun to flow. The current is then only limited by the resistance of the coil wire, the important changing of voltage being missing.
Well, we have seen that direct current

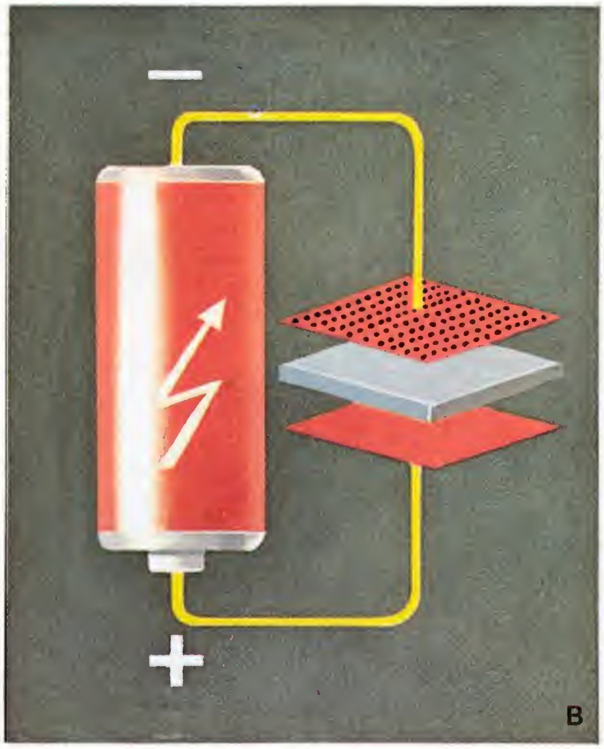
can flow, more easily through such a coil than alternating current. The higher the frequency of the alternating current, the harder it is for this current to flow through the coil, The resistance a coil offers to the flow of alternating current of a certain frequency depends on its dimensions and its number of turns.

ELECTRIC FIELD

Magnetic fields are well known, thanks to the compass and the horseshoe magnet. However, there is also an electric field.

A magnetic field is generated when a current flows through a wire; an electric field is present around an object on which there is a voltage. You know that when you rub a glass rod or a gramophone record with a piece of dry wool or silk cloth, the rod or record can attract dust and small pieces of paper. This is due to the fact that, as a result of rubbing, these objects become electrically charged and electrons have crowded on to the surface. What you cannot see is that an electric field not only attracts particles of dust but also attracts or repels electrons. As far as repulsion is concerned just think what happens when two magnets are brought close together. The north pole of the one attracts the south pole of the other, but two north poles repel one another. Electrons are all negatively charged, so just as "like" magnetic poles repel one another, so also do electrons repel one another.





CAPACITORS

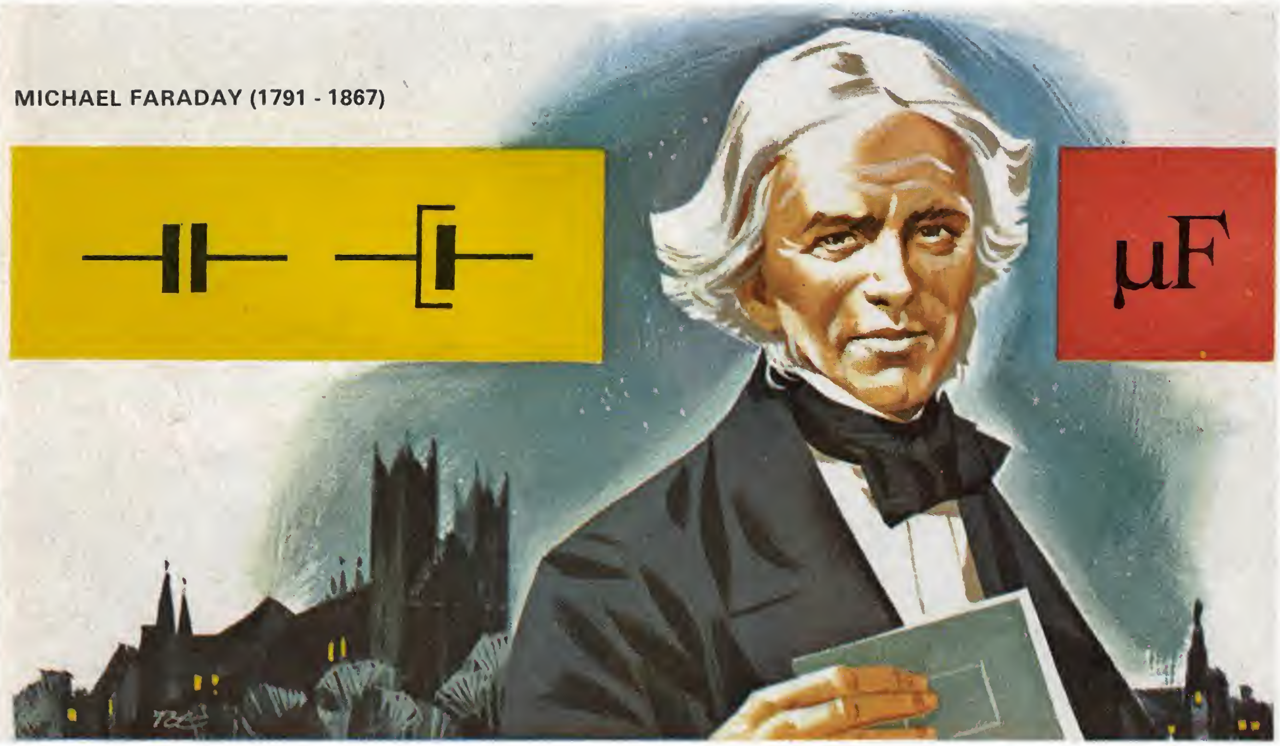
Let us now find out what happens when two metal plates set up as in the illustration are connected to a battery. Electrons flow from the negative pole to the lower metal plate. They have no alternative because there are lots and lots of electrons in the battery all trying to repel one another. The wire connection and the plate give them the chance of pushing a few thousand million electrons out of the battery along the wire and into the plate. Once they have got there they can go no further because the air space will not let the electrons through. Air is not a conductor it is an "insulator". But

an electric charge generates an electric field which goes through the air and reaches the other plate. There are also electrons in this plate. As a matter of fact there are always electrons present in a conductor, even when the conductor is not connected to a battery. The electrons just happen to be present in the metal. They do not flow through it as there is no particular reason to, but they can be moved. As we have just said, electrons are unfriendly and impolite.

Impolite people boarding a train push their way in and use their elbows. Electrons are much worse than people. They are always impolite to one another and can even push at a distance, even when they cannot reach each other with their elbows. The electric field that is emitted from the lower plate therefore pushes electrons out of the top plate, along the wire to the "plus" of the battery. The higher the voltage the more electrons can be pushed away. What happened at the moment we connected the battery to the two metal plates? A current of electrons flowed from the minus pole of the battery to one of the plates and from the other plate to the plus pole of the battery. That is all. Once the "filling up" stops, the electrons on either side of the gap reach equilibrium. They stop moving and no more current flows. Now we quickly connect the battery the other way round to the two plates. Plus is now at the bottom and minus is at the top. The minus pole of the battery again sees its chance to rid itself of some electrons, this time to the upper plate which is, of course, "empty". Once the electrons have reached the plate they repel their brothers and sisters still present on the lower plate with such force that the latter end up in the battery, thus causing a current to flow again until the top plate is charged with electrons. Now compare the second drawing with the first one.

First of all the electrons flowed in the lower wire from left to right, then the other way round. If we keep reversing the poles of the battery an alternating current will flow through the wire. It will be clear to you that if reversing the poles is done very quickly the electrons will fly back-

MICHAEL FARADAY (1791 - 1867)



ward and forward far more often than when the poles are reversed at a slow speed. Instead of reversing the poles of the battery we can apply an alternating voltage. In engineering, alternating voltages are produced in many ways, some of which will be discussed later on.
Two metal plates, parallel, but not touching another are known as a "capacitor". When the frequency of the alternating

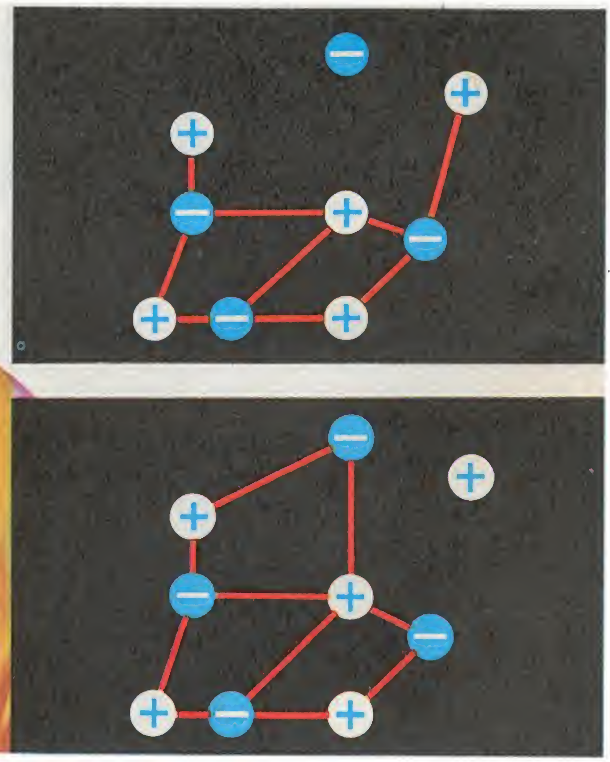
The farad is a very large value, therefore, we normally use the micro farad (μF), which is one million times smaller, and the micro micro farad ($\mu\mu$F), usually called pico farad (pF) which is a million times smaller still. Sometimes use is also made of the nano farad (nF), which is equal to one thousand pF. Thus:
1 F = 1,000,000 μF 1 F = 1,000,000,000 nF
1 F = 1,000,000,000,000 pf or $\mu\mu$F

current becomes greater the current flows more easily through such a ,,capacitor" or "condenser" as it is sometimes called.
A capacitor is thus the exact opposite of the coil. It does not let any direct current through but permits alternating current to flow, particularly if it has a high frequency. The dimensions of the capacitor, that is to say the size of the plates and the distance between them, determine the ,,capacitance". The capacitance is the ability of the capacitor to hold an electric charge. The greater the capacitance, the easier the alternating current can flow through it. The capacitance is measured in farads, shortened to F.

SEMI CONDUCTORS

A loudspeaker needs quite a large current, which is, in fact, thousands of times higher than the currents that flow through your aerial as a result of the radio waves which it picks up. Therefore we need components that amplify the currents we pick up with the aerial. It is possible to amplify, that is, increase the strength of alternating currents and voltages by means of electron tubes (valves) or transistors. In our kits we make use of modern transistors.
The operation of a transistor is a rather complicated matter. In fact it is not only complicated, but rather mysterious. A

transistor has the appearance of a tiny metal or plastic envelope with three or four connections coming out of one end. The envelope however, is only a protection for the actual transistor. This transistor is made of rare, and therefore expensive, materials like germanium or silicon. These are precious and useful elements which are called metaloids.
The metaloids Germanium and Silicon have similar properties to those of metals like copper, iron, silver and gold. Most metals are good conductors of electricity, germanium and silicon however, are not. Substances like paper, rubber and mica are such poor conductors of electricity that they are called non-conductors or insulators. Germanium and silicon are not insulators either, since they do conduct to a certain extent. Therefore they are called semi-conductors. We might, however, also call them semi-insulators.
Germanium and silicon can only be used for transistors in an extremely pure form. If you were to count all the grains of sugar in a four-pound bag, you would find that there were about ten million.



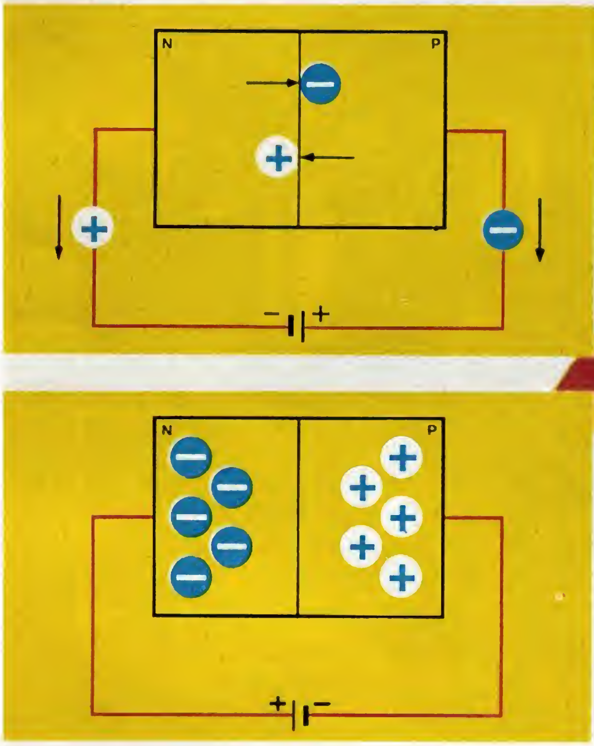
If one grain of sand was present in the four pounds of otherwise pure sugar, the sugar would be "contaminated" to the same extent as the germanium and silicon used for transistors. This should give you some idea of how pure these materials have to be.

In the next chapter we will explain the working of a silicon transistor. The working of germanium transistors do not differ much in principle.

ELECTRONS AND HOLES

We already know that the smallest visible piece of metal contains millions of electrons. Electrons are minute particles possessing an electric charge. This charge is normally not noticable because there are also opposing charges in the metal which cancel it out. If you put identical magnets one on top of the other with the north pole of the one on the south pole of the other, you will see that iron objects are no longer attracted as strongly as before. The opposite magnetic charges

have cancelled each other out.
Like everything in nature, it all depends on balance. Electric charges are either negative or positive, just as magnetic poles are either north or south. Electrons are all negatively charged. If we take an electron (negative charge) out of the metal, there will be a "hole" left. The electric charge of this hole is the opposite of that of the electron. Therefore holes

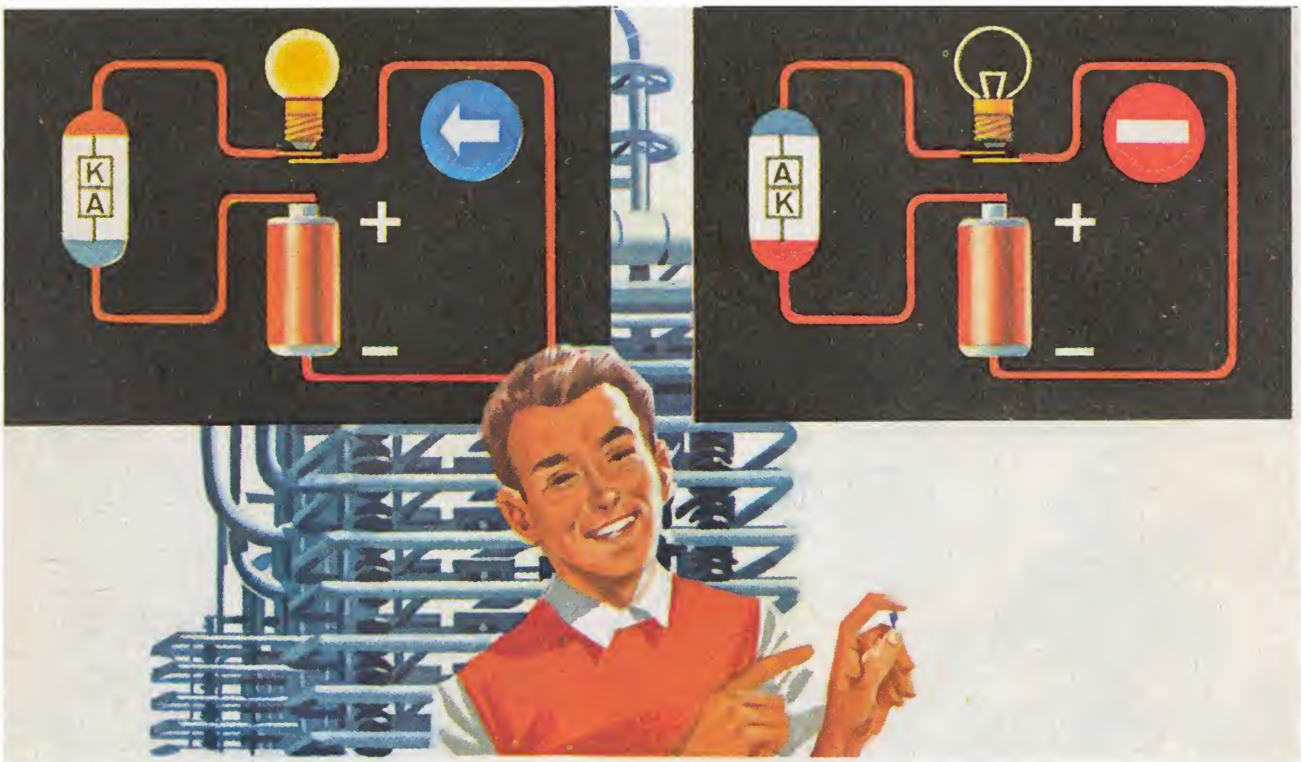


are positively charged. So the charges of the electrons no longer fully cancel out the opposing charges (of all the holes together) which are present.
Now what is the position in pure silicon? It is full of electrons and holes. These electrons and holes however are all firmly fixed in the material. This is why silicon is such a poor conductor. When some phophor is introduced into the silicon, it allows a number of electrons to be moved little more easily. If we put some borium into the silicon we find that some of the holes can be moved a bit more easily as well.
Silicon "doped" with a little bit of phosphor is called N-type Silicon because in this the negative electrons can move. Silicon doped with borium is called P-type Silicon as in this the positive charges can be moved about.

FRONTIER TRAFFIC

If you now place two small slices of pure silicon up against one another, nothing happens, not even if you connect a battery across the pair of them. If however, we put a slice of N-silicon and one of P-silicon together, we find that current flows easily through the pair of them when voltage is put across them. The plate of P-type silicon must then be connected to the plus and the N-type silicon to the minus. (The current generated by this voltage must be very low otherwise the small silicon slabs will be damaged). The ease of flow of the current can be explained as follows:
Opposite charges, like those of electrons and holes attract one another, the same as do opposite magnetic poles. The electrons in the N-silicon are attracted by the holes in the P-silicon. As the elec-

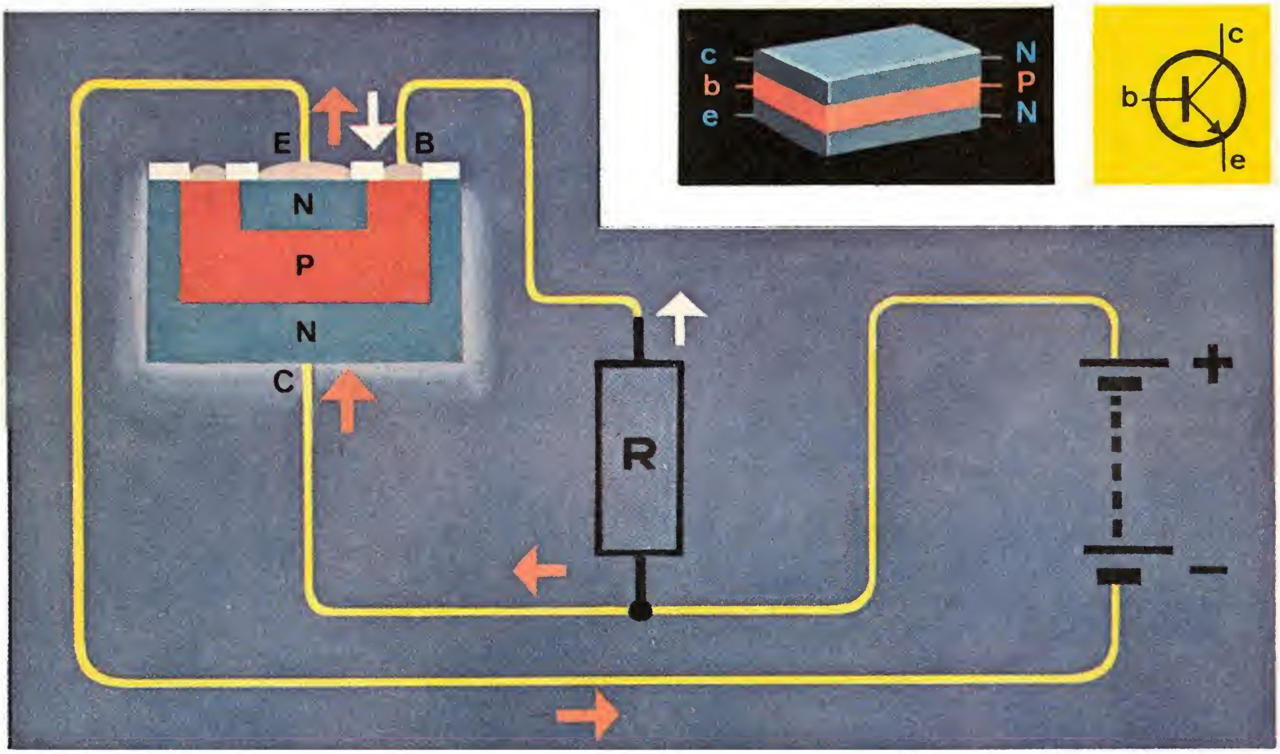
trons can move about within their own slice of silicon, the force of attraction will thus move them towards the junction between N- and P-silicon and some of the electrons may even cross this border. So likewise with the holes which are in the P-silicon.
The battery has been so connected that its minus pole tries to push the electrons in the N-silicon towards the P-silicon, minus pole does the same to the holes in the P-material. These forces are larger than the forces between the holes and the electrons within the P- and N-material respectively. Thus round the junction neither electrons nor holes are left. The battery has won, but at a price. Once the plus pole of the battery has drawn away all the electrons from near the junction, there are no more electrons to follow up



while the positive pole aids and abets by pulling at the electrons. Under the influence of all these forces some more electrons will cross the junction and even pass through the P-silicon. To make up for the loss, the battery supplies an equal number of electrons to the N-silicon which are again pushed and pulled towards the junction which they cross and so on. To the holes the same happens, but, of course, they move in the opposite direction. Next we connect the battery the other way round: plus pole to N-silicon, minus pole to P-silicon.

The plus pole attracts the electrons in the N-material away from the junction. The and hence, no current of electrons. It is the same with the holes.
Such a combination of a slice of N- and a slice of P-material is called a diode- it lets the current pass in one direction only.
The diode converts an alternating current (AC) into a direct current (DC). It is not difficult to discover what happens when an alternating voltage is connected to a "diode" of this kind. During the half cycle, when the voltage on the P-material is positive and negative on the N-material, current flows. During the following half cycle, when the voltage is reversed, no current flows. The current through the diode will only flow in one direction and

is, therefore, direct current, even though it flows with interruptions. The alternating voltage has been "rectified". In our assembly kits, the diode is used in radio receivers and its function there is explained in the relevant chapter. Diode rectifiers are used for example in accumulator chargers.
Accumulators must be charged with direct current but the current we get from our mains is alternating. The accumulator charger therefore contains a rectifier which turns the AC into DC. The diode used in the kits is however not suitable for this purpose. (it is not strong enough).
There is no way of telling by just looking at the diode which of its two lead wires is connected to the N-type material and which the P-type. The diode is, therefore, always marked on the "cathode side". The other lead wire is said to be on the "anode side". You should always pay attention to this during assembly. In the symbol for the diode, the arrow shows the direction in which the holes go through the diode. The electrons thus move against the arrow. The mark put at one end of the diode indicates the negative side; that is, the side connected to the N-material.



TRANSISTORS AMPLIFY CURRENTS AND VOLTAGES

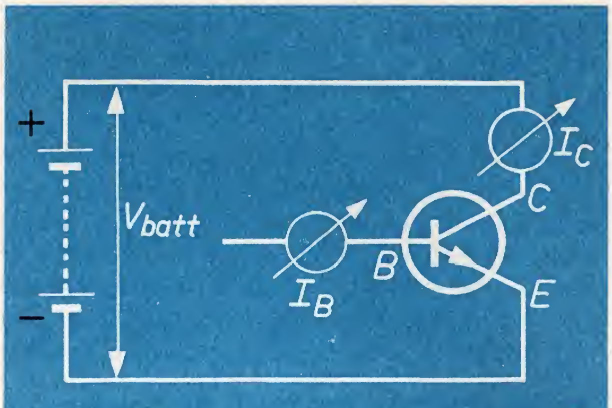
The transistors used in the assembly kits consist of three layers of silicon, namely one layer of P-type silicon with a layer of N-type on either side of it. The middle layer of silicon is called the base (B), one of the N-type layers is called the emitter (E) and the other the collector (C). Let us imagine that we put a voltage between the collector and the emitter of the transistor. (Fig. C).
Very little current will flow. Now we feed a current via R to the base of the transistor. (Fig. D). This resistor (R) is necessary to limit the base current otherwise the transistor will be damaged. When we now measure the various currents we will see that the collector current I_C is considerably higher thant the base current I_B. Let us suppose that the voltage V_{batt}

increases slightly. The base current will become slightly higher. The collector current however is also changing but the change of the collector current is much larger than the change of the base current. For example

V_{batt} = 4.5 V	V_{batt} = 9 V	V_{batt} = $4\frac{1}{2}$ V
Resistor R	Resistor R	Resistor $\frac{1}{2}$ R
I_B = 1 mA	I_B = 2 mA	I_B = 2 mA
I_E = 100 mA	I_E = 200 mA	I_E = 200 mA
I_C = 99 mA	I_C = 198 mA	I_C = 198 mA

Change of the base current 2 — 1 = 1 mA. Thus, we see that whatever the voltage across R may be, the collector current is always 99 times as large as the base current. If we now look at the currents alone, we find that when the small base current is doubled the larger collector current is also doubled. If in a circuit the base current from the transistor is changed in one way or another, the collector current changes in proportion. We can also connect a source of alternating current, e.g. microphone, in series with R. We will then have not only direct current, but also alternating current flowing through the base of our transistor. Such a combination of direct current and alternating current can be regarded as direct current which periodically changes in strength. We will then have a current through the collector of the transistor which also becomes periodically stronger and weaker. These changes in the collector current may likewise be regarded as an alternating current super-imposed on the normal direct current through the collector. As we have just seen, this alternating current will be greater than that through the base; in our example it will be 99 times as large.

In other words, the transistor has amplified the alternating current 99 times. In practice, the amplification can be even greater, a few hundred times, for instance. Transistors are used to amplify the low voltages and currents coming from a pick-up, a microphone or an aerial so that they can operate an earphone or a loud-



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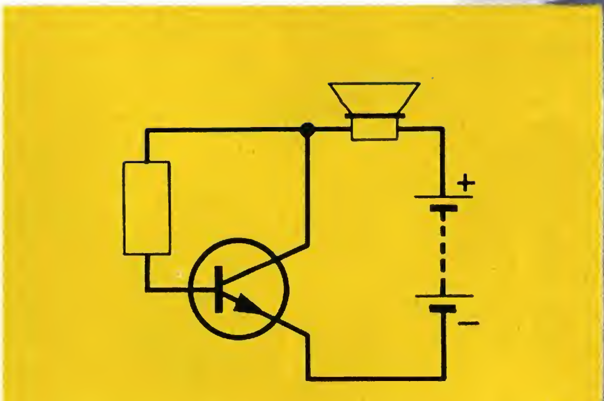

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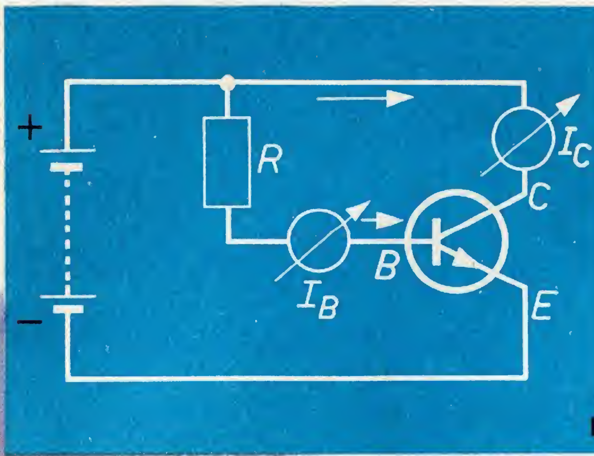

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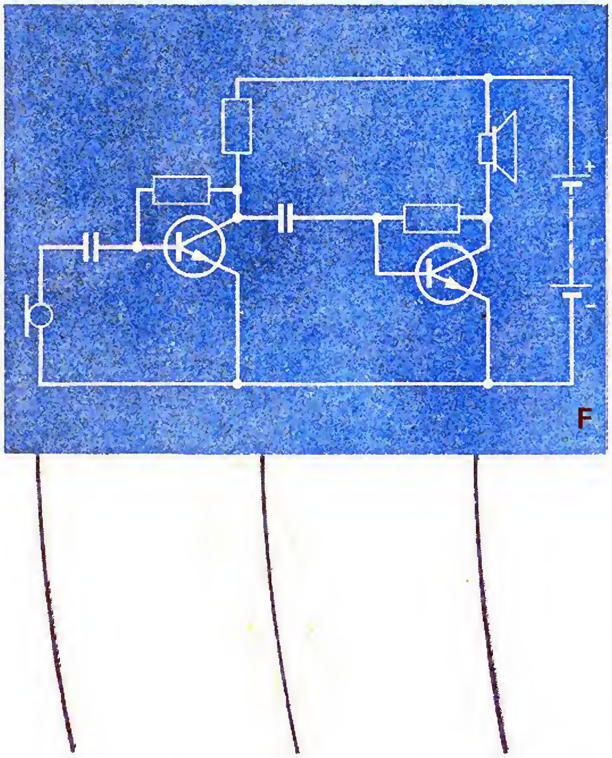
speaker. If one transistor does not give enough amplification, we can use two or even three, one after the other ("in cascade").
By giving the resistor the correct value, we can make sure that the base voltage will also have the right value. A transistor thus needs two kinds of voltages: DC voltage so that it can work at all and alternating voltages for it to amplify. It is of no use to let the collector current, which is in fact the amplified base current, flow through the battery only. What we really want to do with this current is for example to drive a loudspeaker. The loudspeaker is then connected in series with the collector (Fig. E).
When one transistor is followed by another transistor, because more amplification is needed, a resistor is connected in series with the collector. If the transistor does not need to amplify sound waves but a carrier wave (in radio receivers) a coil or a tuned circuit is used instead of the resistor.
By using capacitors, which, as we have mentioned pass alternating current, but not direct current, we can arrange that the alternating current passes from one transistor to the next without the accompanying direct current. If we did not do this, the direct current accompanying the alternating current would upset the operation of the second transistor. The use of coupling capacitors prevents this trouble.
We call this set up a cascade amplifier; the second transistor is driven by the first one (Fig. F). The resistor that conducts a small direct current to the base is now connected to the collector instead of to the battery. This results in a direct current of the collector which remains more stable in case of temperature changes.
As the collector and emitter currents are practically the same, we can connect a resistor to the emitter instead of to the collector (Fig. G). In this case, the base is generally connected to the + and the — of the battery with two resistors. This circuit has other amplifying properties



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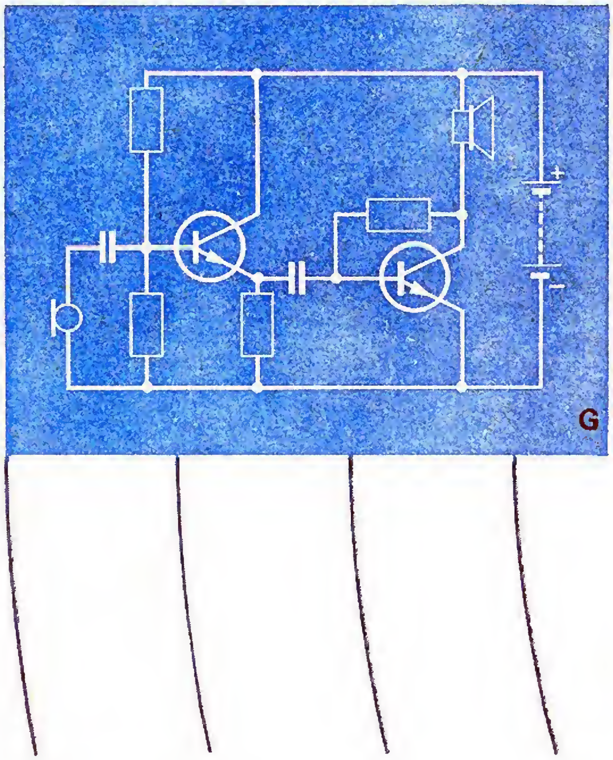

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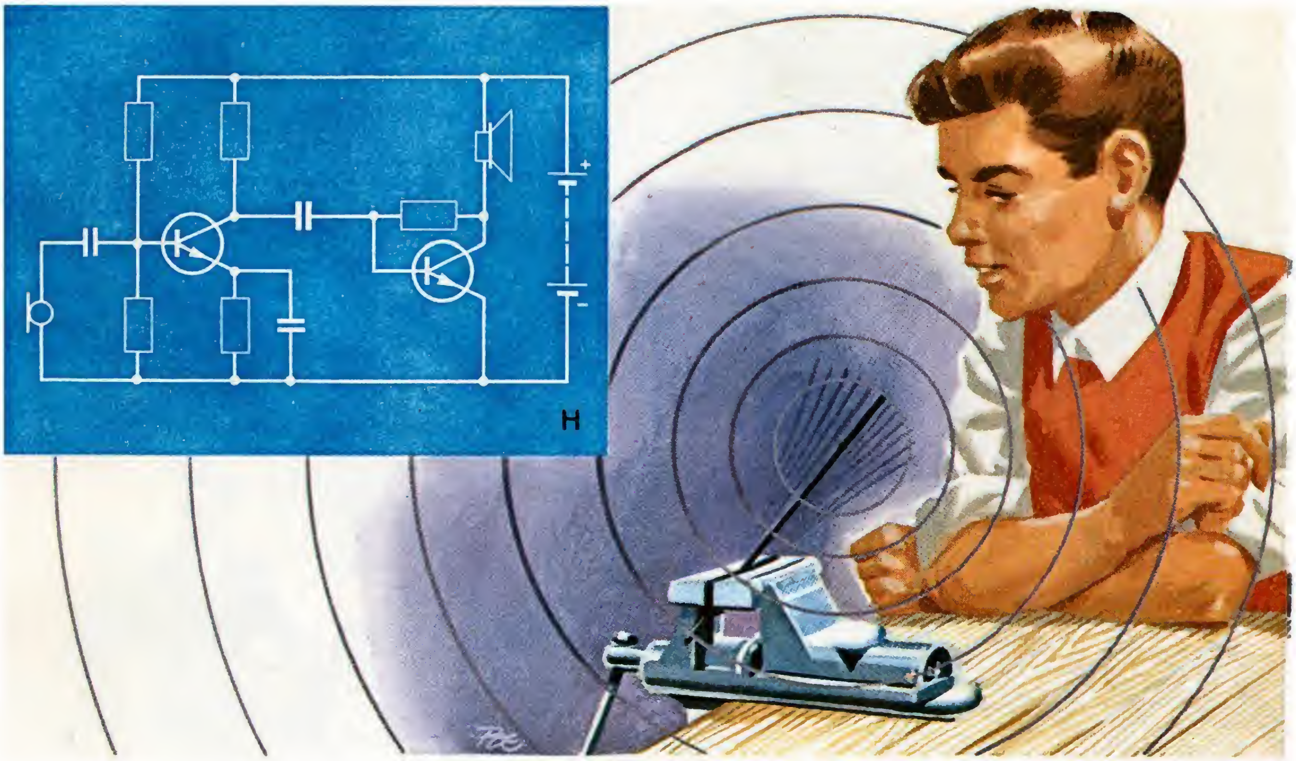
than the circuit of fig. F. Therefore it is also one of the experiments of this kit. A circuit with an emitter resistor and two resistors connected to the base can also be used if we have a resistor connected to the collector (Fig. H). In this case it is desirable to connect a capacitor across the emitter resistor. If the resistors have the correct value the stabilisation of the collector current is better than with one resistor between base and collector, although more components have to be used.

Transistors can also be used as a switching device. In this case the base and the collector currents are not varied by an AC voltage but are either zero or have a certain value. This is called a digital circuit in which the transistor is working as a switch or more correctly as a relay. By giving a small control current to the base, a large current in the collector circuit can be switched on. The application of this principle will be found in some of the experiments of the kit.

ELECTRO ACOUSTICS

Electro-acoustics is the fancy word for everything to do with picking up, amplifying and reproducing sound.

What is sound? Sound is what we call all audible vibrations of the air. When you throw a stone into the water you see the



ripples on the surface. Circular waves spread outwards from the point where the stone fell into the water. When you clap your hands similar waves are generated in the air. You cannot see these waves but they are real nevertheless. You can hear them all right, for our ears are intended for the purpose of perceiving such air waves. The water waves go up and down, as you can see quite clearly, if, near the place where you have thrown the stone into the water, there is a little piece of wood. This is moved up and down by the waves but otherwise remains stationary. In the air, waves can travel like that too. Imagine a strip of metal locked in the jaws of a vice on a work-bench. If you bend the free end of the strip and then release it, it will spring forward, going beyond its starting position, spring back again, then forward again and so on, each time passing its original position of rest. In fact the strip is vibrating. Such vibration makes the surrounding air vibrate too. Thus waves of air move from the vibrating strip in all directions, just as in our example of the stone thrown in water.

If such a wave catches your ear, you will hear a note. The more vibrations per second the strip makes, the higher the note is. The number of vibrations per second is called the frequency of the note. One vibration per second is called 1 Herz

(1 Hz) or 1 cycle per second (1 c/s). Our ear can perceive notes from about 50 Hz to about 20,000 Hz. A dog can hear higher notes; think of the silent dog whistle.

THE LOUDSPEAKER

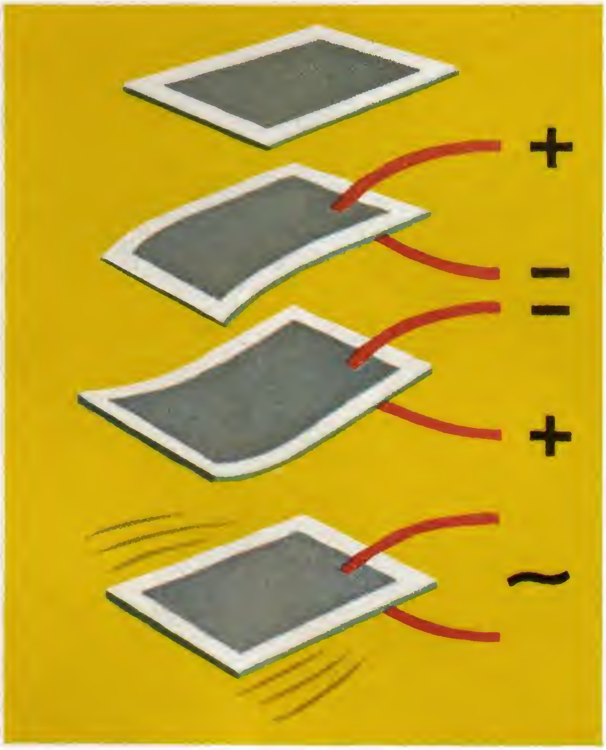
All musical instruments are based on the fact that the air is made to vibrate rapidly in one way or another. When we talk or sing, for instance, the air vibrates. The loudspeaker we use in our radio and gramophone amplifier is a device which causes the air to vibrate.
Just imagine you have a round disc which you move backwards and forwards a few hundred or a few thousand times a second. The vibrating disc will also cause the air to vibrate. This generates sound. The question is how do we get the disc to vibrate? To do this we fix a coil to the disc and place the coil near a magnet, for instance a horse shoe magnet with which you are familiar. Now we send an electric current through the coil. What happens next? The coil behaves just like a magnet with a north pole and a south pole. When the direction of the current is such that the north pole of the coil will repel the north pole of the magnet, the disc will move forward. If we now reverse the current we shall change the magnetic poles of the coil so that there is now a

south pole (at the end previously north) which is attracted to the north pole of the magnet. The disc will now be moved backward. What happens now if we send an alternating current through the coil? That is a current which keeps changing direction, lets say one thousand times a second (an alternating current with frequency of 1000 c/s). The coil will thus be attracted and repelled one thousand times per second by the magnet. The coil and the disc which is fixed to it will thus be vibrated one thousand times per second to and fro and we hear a clear tone. This is the principle of the loudspeaker. The real construction is somewhat different in order to ensure that a loudspeaker as powerful as possible is obtained with a magnet which is as small as possible.

MICROPHONE WITH MOVING COIL

We thus know how we can change an electric current into a sound vibration. But, how can we do it the other way round? How can we turn a sound vibration into an electric current? We do it with microphones. There are several sorts of these. One type, which is often used, works in the very same way as a loudspeaker does, but the other way round. Just imagine that there is a sound somewhere and that this sound strikes

against the disc of the loudspeaker (the disc is called the loudspeaker diaphragm). This diaphragm then starts vibrating. When the diaphragm starts to vibrate, the coil does likewise. A little while back we said that when a coil is in a magnetic field and the magnetic field is changed, a voltage is generated in the coil. When the coil vibrates, its place in the magnetic field changes continuously. This is just the same for the coil as if the magnetic field was changed. In the vibrating coil of a microphone, then, some small electric voltages are generated. These little voltages can be amplified in a way we told you about, and are then fed to a loudspeaker. The alternating currents now flow through the loud-speaker coil so that the loudspeaker diaphragm is made to vibrate and the original sound is heard again.



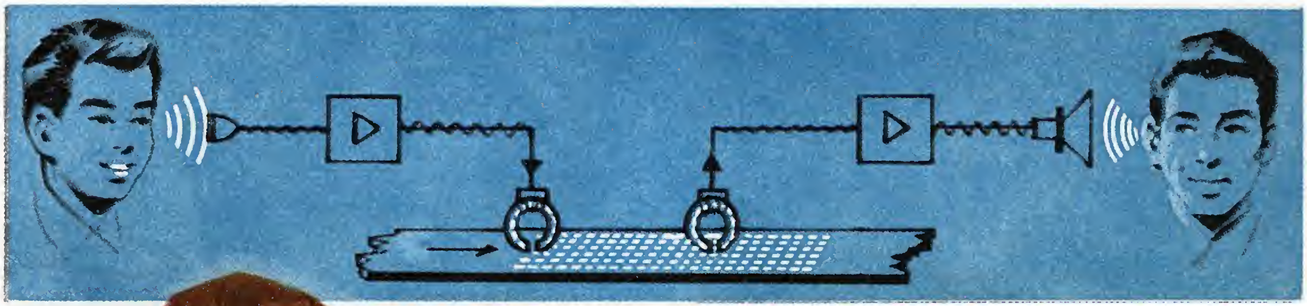
CRYSTAL MICROPHONES

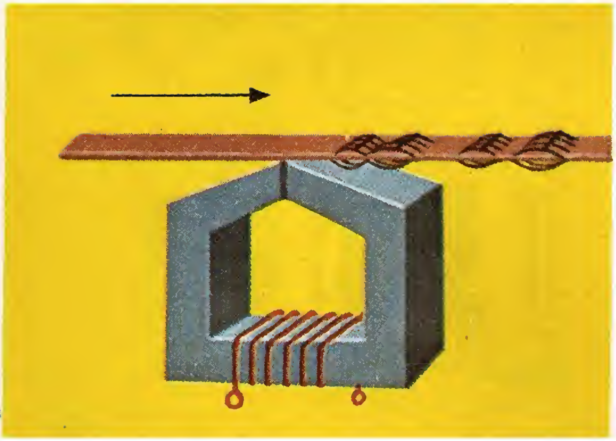
There is however another method of generating sound or picking it up, by using certain materials which have a very peculiar porperty. One such material is known as Rochelle salt. If you take a little slab of this, apply a conducting layer to each side and then connect a battery to the two conducting layers, something happens. The slab starts to bend to one side. If you then connect the battery the other way round the slab curves the other way. Do yo follow? When you connect an alternating current the slab it bends to and fro. If you attach a diaphragm to this slab of Rochelle salt, the diaphragm will start to vibrate and you hear a tone. The opposite is possible too. When sound sets the diaphragm vibrating, the Rochelle salt slab is bent backward and forward and a voltage is generated between the two conducting layers on the slab. Used in this way it is called a crystal micro-phone.

CRYSTAL PICK-UP

In most pick-ups used in gramophones, Rochelle salt slabs are used. The vibra-tions come from the grooves in the gramophone record. When you examine

such a groove under a magnifying glass you will see that it is not just a spiral line but that the line wriggles to and fro a little. The wavy line of the groove corresponds with the air vibrations of the original sound.
The gramophone needle resting in the groove is also pushed to and fro by the groove. This needle is fixed to a slab of Rochelle salt, which is therefore also bent to follow the movements of the needle. Again as a result of being bent to and fro, an alternating voltage is generated between the conducting surfaces on the Rochelle salt. A pick-up is thus, as it were, a microphone with a needle on it, which is not vibrated directly by the air vibrations but by means of the needle in the groove of the record.





TAPE RECORDER

In addition to the gramophone you will also have heard of the taperecorder for the reproduction of sound. With the tape-recorder we can record the sound ourselves. The sound is picked up by means of a microphone and amplified electronically. This sound is passed to an electromagnet, the "recording head", in the form of current variations. A sound tape i.e. a tape with inumerable particles of magnetic iron oxide, is now passed at constant velocity along the recording head. The current fluctuations are then converted by the electromagnet into magnetic fluctuations.

The sound tape has the property of retaining the pattern of magnetic fluctuations. In this way the sound is recorded as a magnetic pattern on the sound tape. During play-back, the play-back head scans the magnetic track and thereby becomes energized. The play-back head converts the magnetic fluctuations into current fluctuations. These current fluctuations are amplified and passed to the loudspeaker, which reproduces them again as sound.
The magnetic pattern is retained on the tape until the tape is made magnetically neutral again with a special head, - the erasing head. The erasing head is also an electromagnet which in this case is

supplied with a strong alternating current of a very high frequency.

TELECOMMUNICATION

Telecommunication means something like "traffic at a distance". By traffic, however, you should not imagine motorcars, trains and aeroplanes, but the transfer of information. This can be by telegraphy, telephony, radio-telephony, picture-telegraphy or television. What is important here is that there is always a distance to be bridged. A house telephone or intercom is just as much a piece of telecommunication equipment as the installation which will eventually be used to send messages to the first people landing on the moon.

When you call out of the window to your friend who lives on the opposite side of the road, it is hardly telecommunication. Telecommunication is the transmission of messages over practically any distance you wish. You cannot do that by talking or even shouting. If your friend lives a mile away then you can yell as hard as you like, but he will not hear you. It is only by electronic means that it is possible to bridge any distance, and telecommunication is thus the electronic transmission of information. One of the oldest but still very important methods in telecommunication is telegraphy. Telegraphy is very well suited for the transmission of information over long distances.

One of the circuits in this kit is a telegraph; that is a set with which you can send morse signals. The morse code is fed from your morse key along wires to an earphone or loudspeaker and these wires can be very long. In this kit you will not get wire a mile long. In any case you are not allowed to fit wires over the street as you like - you have got to have the approval of the Town Council and of the Post Office authorities and we are afraid you would not get it. If your friend lives nearby and in the same block, it might be possible to fix up a connection between his and your room.

MORSE TELEGRAPHY

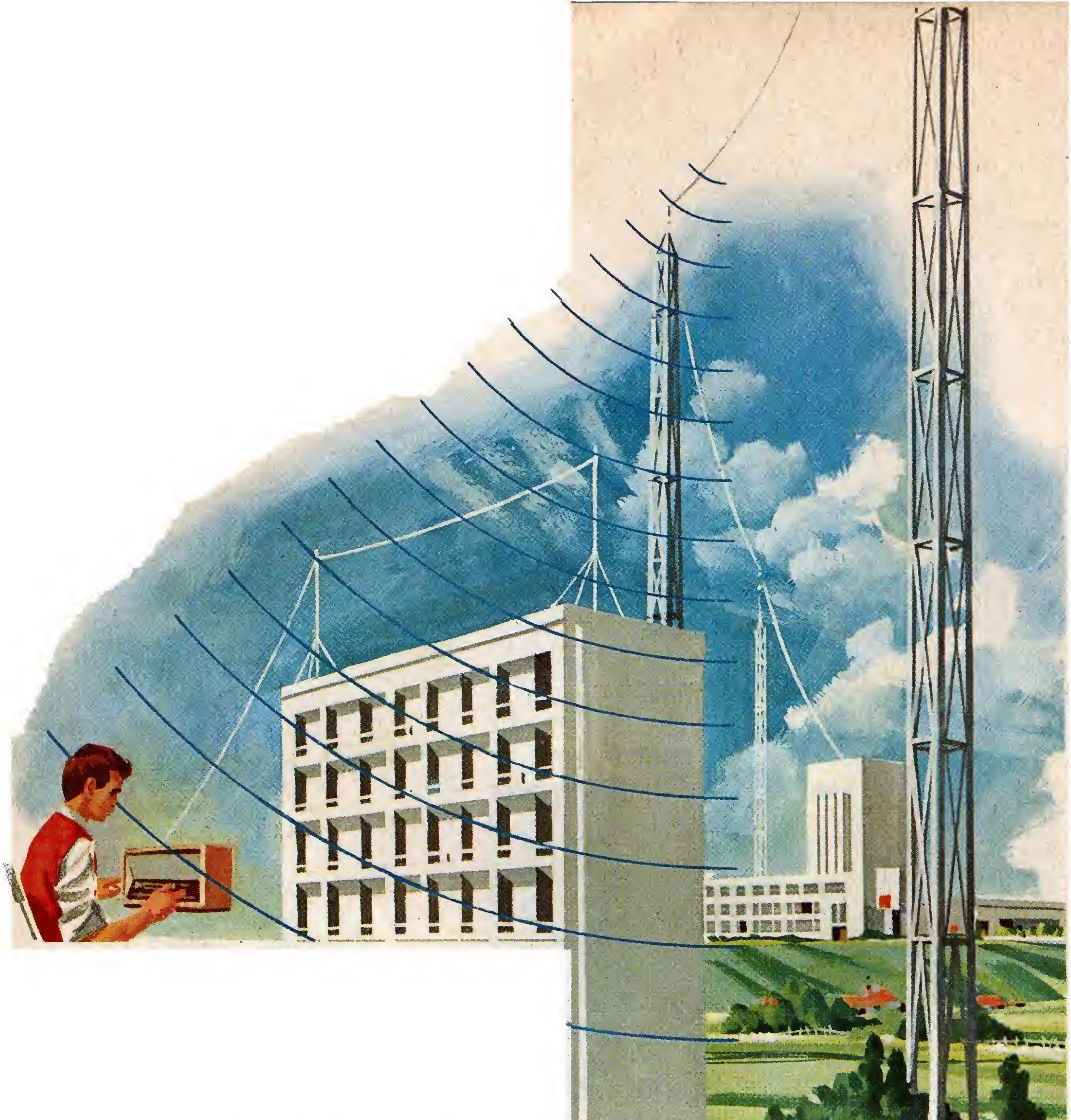
There is an international agreement that a dash should last three times as long as a dot. The rest interval between the parts

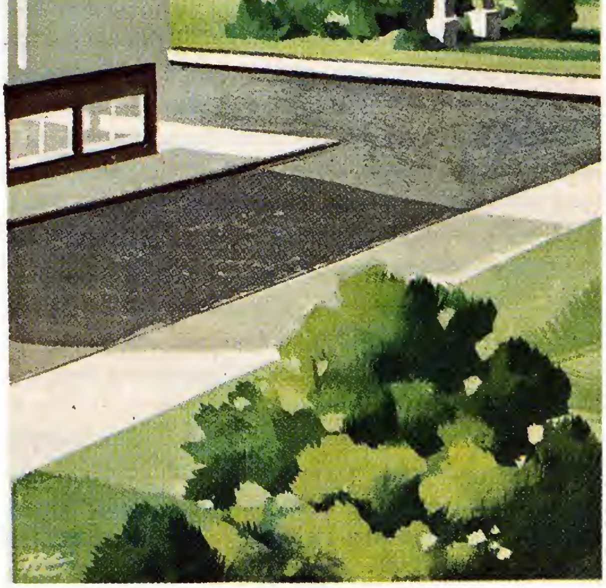
of the same letter lasts as long as 1 dot. The rest interval between two words should last as long as 5 dots. In between two letters of the same word is a space lasting 3 dots. You will note that you attain the correct speed with the least effort if for the dot you say quickly "de" and for the dash you take a bit longer and say "dah". Thus the "a" sounds as "de dah".

RADIO

You no doubt know what radio is but not how it works. A radio receiver resembles a gramophone amplifier halfway, but instead of a pick-up it has a section whose

A	·—	P	·——·
B	—···	Q	——·—
C	—·—·	R	·—·
D	—··	S	···
E	·	T	—
F	··—·	U	··—
G	——·	V	···—
H	····	W	·——
I	··	X	—··—
J	·———	Y	—·——
K	—·—	Z	——··
L	·—··	Ä	·—·—
M	——	CH	————
N	—·	Ö	———·
O	———	Ü	··——
1	·————	6	—····
2	··———	7	——···
3	···——	8	———··
4	····—	9	————·
5	·····	0	—————
Call signal	—·—·—		

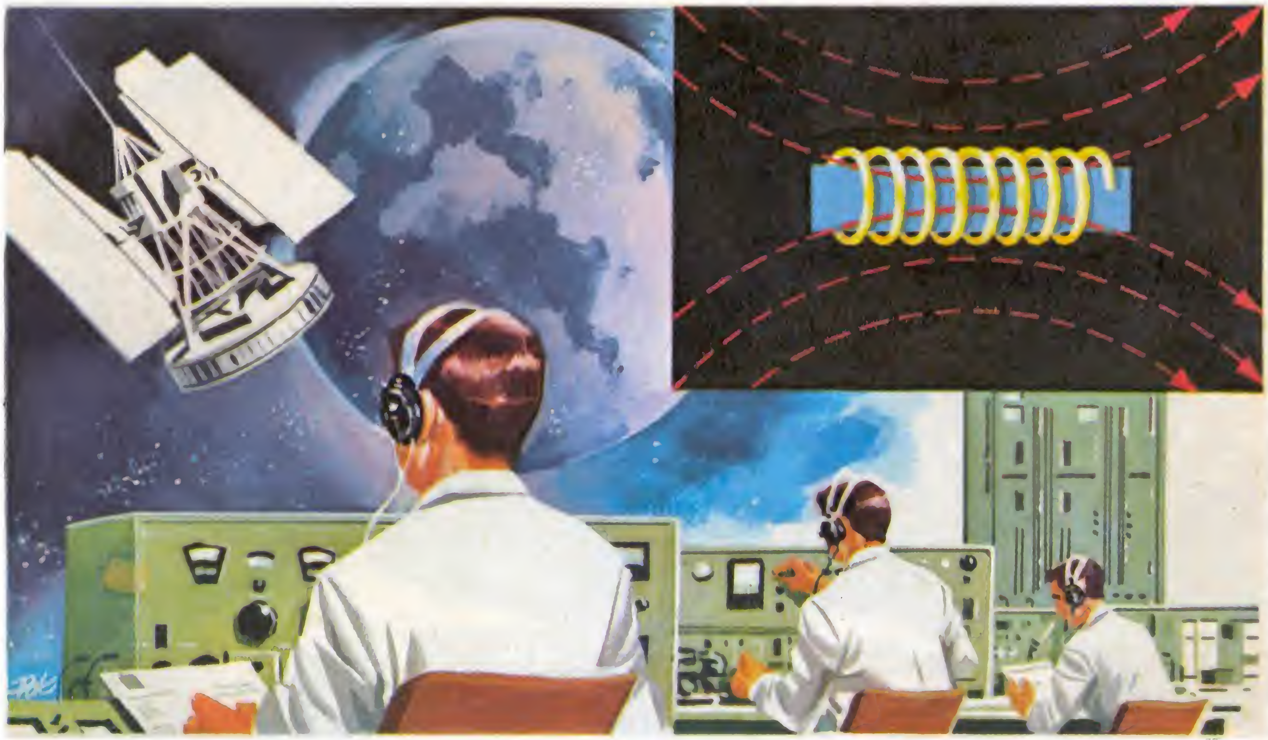




working is probably new to you. Do you remember how the capacitor works? An alternating current can flow through two parallel metal plates, even when they do not touch one another. We shall now replace one of these plates by the earth. This is of course not of metal but it can conduct current. The other plate we replace by a long metal wire, stretched above the earth. This is again a kind of capacitor. If we now connect an alternating current to the metal wire - the aerial - and the earth, an alternating current can flow through this capacitor we have made. The higher the frequency of the alternating current, the greater the current which can flow through it.

Now we have already said that what we call an electric field is generated between the two plates of a capacitor. This happens here too. Between the aerial wire and the earth an electric field is generated, but that is not all. You know that a magnetic field is emitted from a coil when a current flows through the coil. This is also true of a straight wire, so that a magnetic field is generated about

very high frequency that they behave in exactly the same way as light and do not pass the horizon.
We have already said that an aerial must be compared to a capacitor. So long as the aerial is not particularly big the capacitance of this capacitor is relatively small. That is why only alternating current of very high frequencies can be sent successfully through such an aerial.



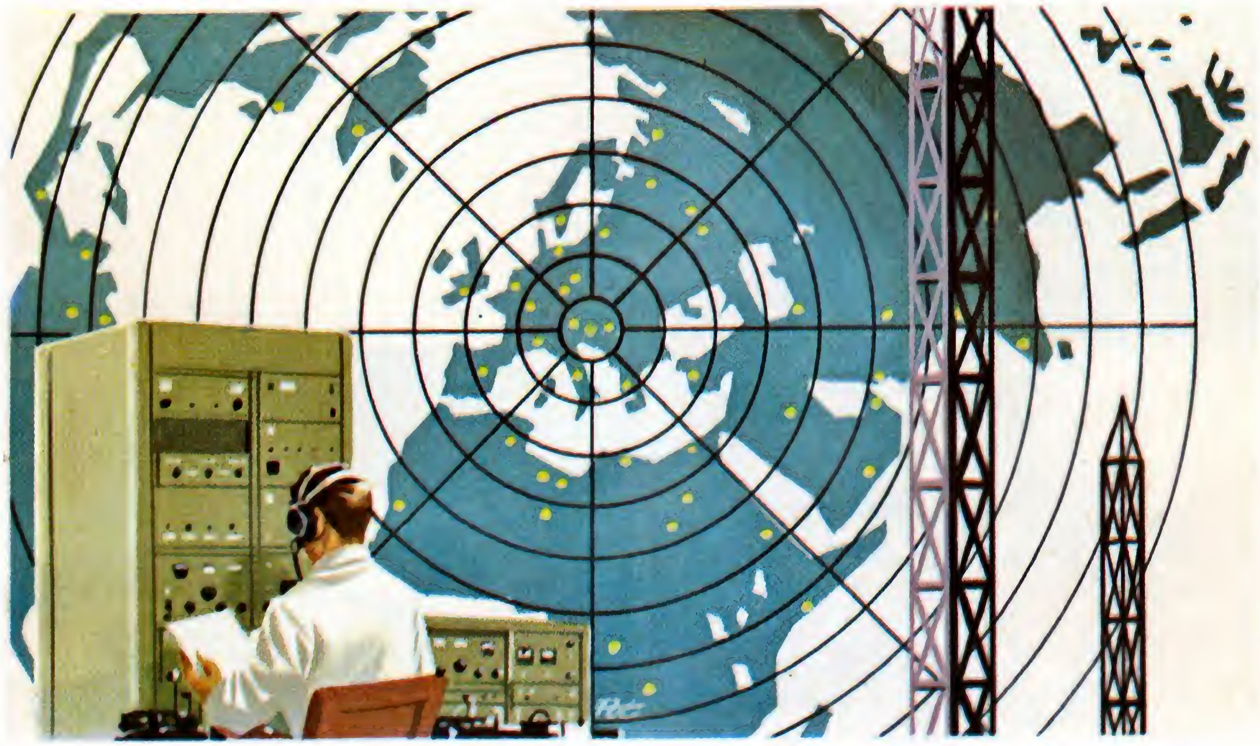
the aerial wire and the wire leading to it. What have we now? When we connect an alternating current between aerial and earth, an electric and magnetic field occur together, and simultaneously. A combined field of this nature is called an electromagnetic field. What happens now? An electromagnetic field like this propagates itself very far. It propagates itself through space, roughly in the same way as light does. In fact light is also an electromagnetic field. The radio electromagnetic field we are dealing with behaves in a somewhat different way, however. Light, as yo know, does not pass the horizon. Radio waves, except in special cases, do. It is only when the radio waves are of a

The frequencies can be 100,000 c/s (100 kc/s) or even higher, for instance 1,000,000 c/s (1 Mc/s).
What happens now when the electromagnetic field strikes an aerial which is some distance away from the transmitting aerial? In this case the field generates a voltage between the wire of the receiving aerial and the earth. If we now connect a coil between the aerial and the earth, the result will be a current running through the coil. This is a very, very small current but with the help of transistors it can be further amplified. The field is however, electromagnetic and the magnetic part of this field will flow directly through what we call the

aerial coil. This magnetic part will itself generate a voltage in a coil as you may remember. We can therefore drop the aerial wire and use a coil as a receiver aerial.
However, you will realise that an ordinary coil can never capture as much of the electromagnetic field as an aerial which is perhaps ten or twenty yards above the ground and may be ten or twenty yards long. A good out-side aerial has a far greater receiving capacity than any little coil.
What happens now if we put an iron core in such a coil? Iron has the property of attracting and concentrating a magnetic field. When a magnetic field is of a very high frequency, ordinary soft iron cannot follow the changes and other materials, such a ferroxcube are used. A ferroxcube core in a coil collects so much magnetic field, that the coil behaves like a far larger coil. Without the ferroxcube core the aerial coil in you radio receiver would have to be almost a yard in section instead of just $\frac{3}{8}$ inch in order to give the same results. Now when we send an alternating current with a frequency of 1 Mc/s through a transmitting aerial, an alternating voltage of the same frequency will occur in a receiving aerial, even hundreds of miles away, irrespective of whether this is just a wire on the roof or what is called a ferroceptor, that is, a coil with a ferroxcube core.
However, a vibration of 1 Mc/s cannot be heard and so we cannot listen to this wireless wave directly. We can however, use it to carry our music, speech or telegraphy signals. First an example of telegraph:.
Just imagine you can amplify the currents flowing through your aerial coil suff-ciently to light a little lamp. When the transmitter broadcasts for a very short time the lamp lights up for a short time and when the transmitter broadcasts for a somewhat longer period, for instance, a half a second, the lamp will burn for half a second.
Now imagine you have a transmitting key connected in the transmitting aerial. Aerial current only flows when the transmitting key is pressed down. If you

let an operator do that, then dots and dashes are broadcast which, when put together, form letters, words and sentences.

When a second operator looks at the lamp in the receiver he sees the dots and dashes and knows what is being tapped out hundreds of miles away. When transmitting sound things are set about in rather a different way. Just assume that you now? The carrier wave becomes stronger and weaker one thousand times per second. This getting stronger and weaker is far too fast and the lamp cannot follow it. If we replace the lamp by a loudspeaker we hear . . . . nothing. The diaphragm of the loudspeaker would have to move back and forward one million times per second, a task it cannot perform as it is far too heavy.

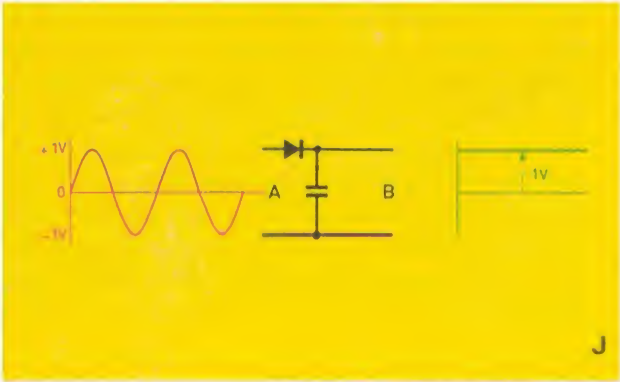


replace the morse key by a variable resistor. When the resistance is small a large amount of current goes through the transmitting aerial; when the resistance is great a small current will flow through the transmitting aerial. If somebody in the broadcasting station turns the resistor knob, the lamp in the receiver will burn either brighter or less brightly. Assuming he turns the knob back and forward three times per second then the little lamp in the receiver will also burn brighter or less brightly three times a second. Now let us assume that he does not do this three times a second but for instance a thousand times a second. What will the transmitted wave look like

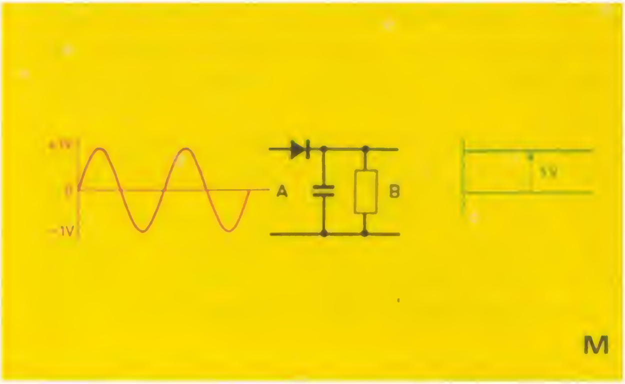
We want to reproduce the 1000 Hz again and therefore we rectify the carrier wave which has been modulated by it.

This rectifying process goes as follows: When we feed an AC voltage of 1 V. to the terminals A, we will measure a DC voltage of 1 V. at the terminals B (Fig. J). Only (he positive pulses of the voltage can pass the diode and charge the capacitor to 1 volt.

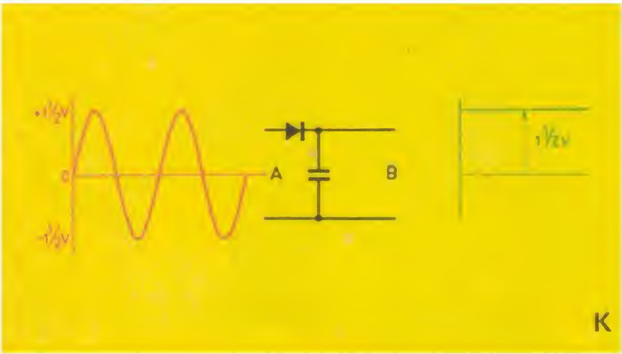
If we raise the AC voltage to $1\frac{1}{2}$ V. the DC voltage will also rise to $1\frac{1}{2}$ V. (Fig. K). If we lower the AC voltage to $\frac{1}{2}$ V. then the DC voltage will remain $1\frac{1}{2}$ volt, however, because the capacitor cannot discharge (Fig. L). We now switch a resistor in parallel with the capacitor, and then the



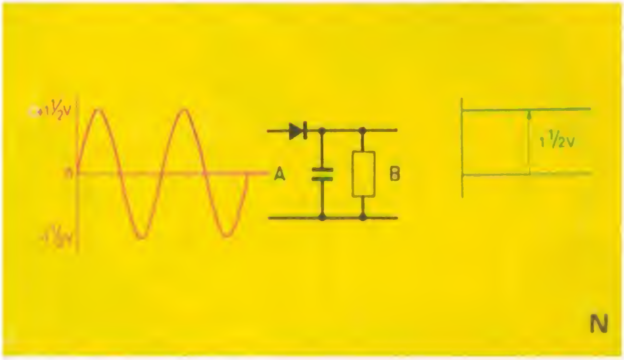
J



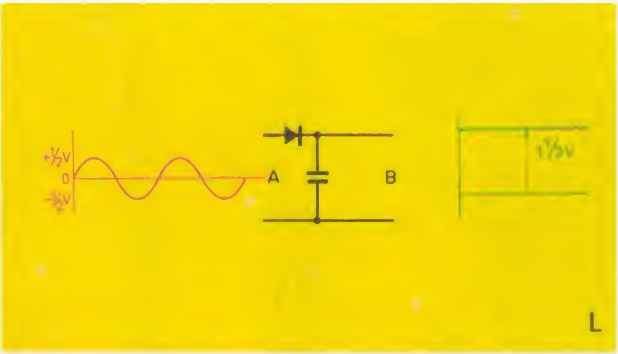
M



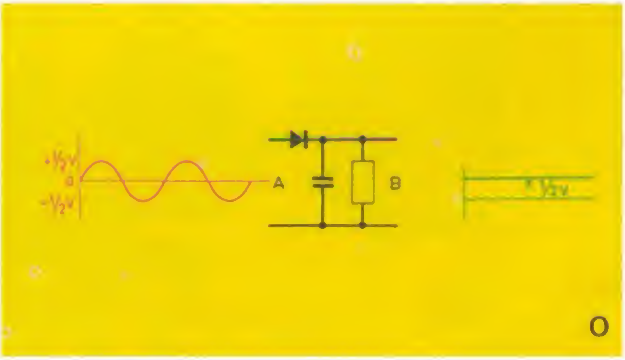
K



N



L



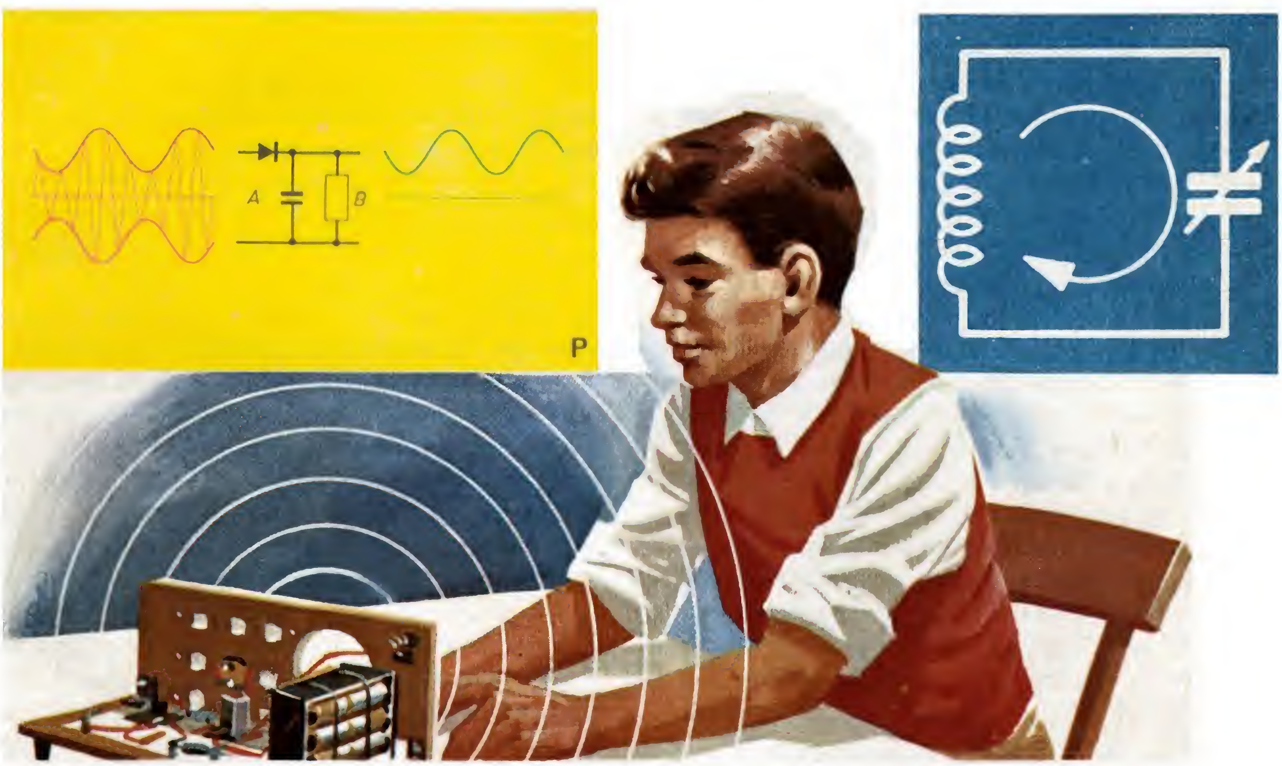
O

capacitor can discharge over the resistor and the DC voltage will follow the AC voltage in value (Fig. M, N, O). Now take the modulated carrier wave, which is in fact a varying AC voltage, and feed it to the terminals A. (Fig. P).
At the terminals B. we only get the DC voltage variation.
In reality the resistor is the loudspeaker. The DC variation activates the coil and the 1000 Hz is reproduced by the loudspeaker.
It is of course impossible to modulate the carrier wave with a knob, but we can e.g. use a microphone as a modulator instead. Then the carrier wave, will be modulated in accordance with the sound vibrations which have struck the microphone. If anyone sings a high note in front of a microphone then the carrier wave is modulated with a high note. If he sings a low note, the carrier wave is modulated with a low note. The receiver will thus reproduce these notes exactly.

TUNING

Of course you have known for ages how to tune a wireless receiver. It is a different thing however to know precisely what takes place. We have told you that the resistance to alternating currents of a capacitor drops as the frequency gets higher. On the other hand the resistance

to the alternating current of a coil increases the higher the frequency gets. What happens now if we connect a coil to a capacitor? At one particular frequency the A.C. resistance of the coil will be exactly equal to the A.C. resistance of the capacitor. It depends entirely on the values of coil and capacitor at what frequency this takes place, and something very curious happens at this frequency. If the capacitance of the capacitor is changed, then this phenomenon, known as resonance will occur at another frequency. All transmitters broadcast a carrier wave and the frequency of this carrier wave differs for each transmitter. At a given position of the tuning capacitor only one transmitter will bring about a powerful circular current. The circuit is therefore in resonance for that one



transmitter, but not for any of the others. The other transmitters are therefore heard much less clearly, so that in most cases they are no longer audible. If we now turn the capacitor, the circuit can come into resonance with the carrier wave of another transmitter and we receive this one instead.

The currents which flow through coil and capacitor are, of course, identical. This is not quite so strange for, as you know, the same voltage and the same resistance means the same current.

What is odd, is that they chase each other in circles. The total current seems to flow in a circle through coil and capacitor and keeps going round and round as if it did not want to leave. It is so pleased that the A.C. resistances of capacitor and coil are the same that at the particular frequency, the current through the coil and capacitor becomes very high. At all other frequencies this current is much smaller.

ELECTRONIC MEASURING AND SIGNALLING

In the technical field and in daily life, a great deal has to be controlled and measured. Both in the elementary school and in the secondary school, to say nothing of technical colleges, pupils are

still plagued with sums in which measurements are carried out. So many pints of water in so many pints of wine, or the container out of which water flows, and what happens when, etc. etc.
With the help of electronics you can measure how much petrol there is left in the tank, what the temperature of an oven is, whether the floor is too damp and, for instance, whether a mixture of two materials is in the proper ratio. When you mix two materials in a machine, it may be possible not only to measure whether the mixture ratio is correct, but also to regulate the taps, in such a way that the correct ratio is automatically maintained.
You can use controls to ensure that the temperature in a room remains constant, irrespective of whether it is cold or hot outside. Just think of the refrigerator. It is also possible to switch on a lamp after a certain period of time, determined in advance. Electronic signalling can also be used as a warning, in the form of a flashing light, that danger is in the offing, or as a smoke detector to warn against fire in buildings or stock rooms. Electronic signalling is therefore extremely useful.
You can no doubt think of many ways to make practical use of the circuits in the kit.